Ballistic Research
Laboratory Report No. 233

ESM/EWC/eme
Aberdeen Proving Ground, Md
April 2, 1942.

EXPERIMENTAL DATA FORMING THE BASIS FOR THE BOMBING TABLES BT-1100-A-3 FOR THE BOMB, DEMOLITION, 1100-LB., M33

Abstract

This report records the essential data on which the bombing tables, BT-1100-A-3, are based. A short description of the bomb is given as well as the mechanical constants of the bombs used. The methods used in range bombing and the methods of obtaining essential data are described. Also given are the methods used to determine the ballistic coefficients, as well as the methods used in constructing the bombing tables. Graphs showing the results of range bombing and graphs showing the fitted C : Y relations are included.

I. Purpose of Report

The purpose of this report is to record the essential details of the experimental work, the computing methods and the experimental data upon which the bombing tables, BT-1100-A-3, for the Bomb, Demolition, 1100-LB., M33 are based.

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II. Description of Bombs

The Bombs, Demolition, 1100-LB., M33 used in range bombing for the bombing tables, BT-1100-A-3, were made in accordance with Ordnance Department Drawing Number 82-0-15, dated September 27, 1934, and subsequent revisions, including that of May 14, 1940.

The bomb is a standard demolition bomb of the cylindrical M30 series. The bomb body is made of steel and is 0.43 inch in thickness in the cylindrical part. The bombs dropped during 1938 and 1939 were assembled with Fuze, Bomb, Nose, M103 and Fuze, Bomb, Tail, M102. The M103 Fuze is an instantaneous-short delay nose fuze to be used with the M series demolition bombs. Both the M103 and the M102 Fuzes are vane type fuzes. All the bombs dropped in this range bombing program during 1938 and 1939 were equipped with aluminum box-type fins. The bombs dropped during 1940 were assembled with Fuze, Bomb, Nose, M103 and Fuze, Bomb, Tail, M106. The M106 Fuze is an inertia-plunger type fuze with a 45 second delay. All the bombs dropped during 1940 were

equipped with steel box-type fins. Although the drawings cited above specify that the bomb body is to be filled with TNT, correspondence 00 471.623/2791 dated April 14, 1938, specifies that it is to be loaded with 50/50 Amatol. The ratio of the weight of the 50/50 Amatol bursting charge to the total weight as dropped is 54 per cent.

III. Preparation of Bombs

The empty bomb bodies with their components were shipped to the Proving Ground where they were inert loaded and their components assembled. In order to obtain the highest uniformity of flight of which the bombs are capable, it is necessary that the variation in mechanical constants from bomb to bomb be kept as small as possible. In order to accomplish this, the bombs were loaded with a mixture of sand and soot in which the proportion of the two materials was adjusted to give the mixture a density equal to that of 50/50 Amatol, so that the specified weight of the completely loaded bomb was obtained when the cavity of the bomb was completely filled. Before being loaded into the bomb, the mixture was carefully blended in order to secure a uniform density.[1]

That this method is adequate is indicated by the values of the mechanical constants given in the next paragraph.

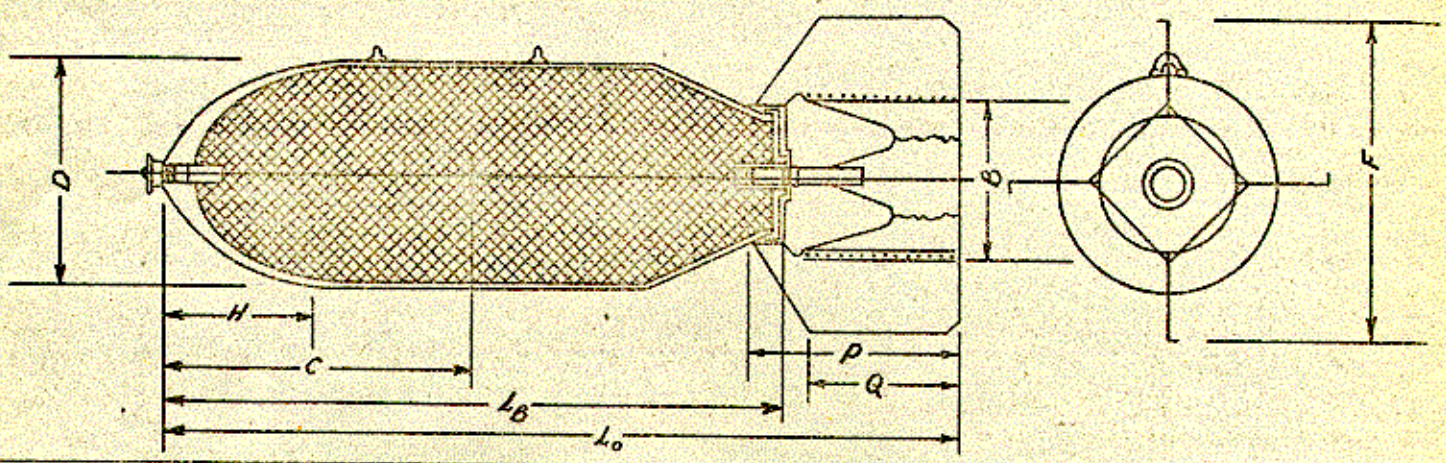
IV. Mechanical Constants of Bombs

The mechanical constants of each bomb were determined before it was loaded into the airplane. The detailed results of these measurements are given in Appendix A. A summary of the results for the Bomb, Demolition, 1100-lb., M33 is given in the table below:

[1] A more complete description of the method used in order to control the mechanical constants of the bombs used in the range bombing program is given in a memorandum prepared in the Ballistic Research Laboratory: "Procedure for Determination of the Mechanical Constants of Bombs".

PHYSICAL CHARACTERISTICS
BOMB, DEMOLITION, 1100-LB., M33

DRG. NO. 82-0-15 REV. 5-14-40



PRINCIPAL DIMENSIONS

DIMENSION	INCHES	CALIBERS	REMARKS
D	19.55	1.00	AS GIVEN ON DRAWING
B	13.25	.68	AS GIVEN ON DRAWING
F	27..	1.38	AS GIVEN ON DRAWING
L_o	68.66	3.51	AS GIVEN ON DRAWING
L_B	52.6	2.69	AS GIVEN ON DRAWING
H	27.1	1.39	AS GIVEN ON DRAWING
P	17.9	.92	AS GIVEN ON DRAWING
Q	12.6	.65	AS GIVEN ON DRAWING
C	26.84 σ=0.237	1.37	MEAN FROM RANGE BOMBING STEEL FINS ALUMINUM FINS-26.56, σ=0.201
C	26.0±.25±.5		OF BODY ASSEMBLY AS PRESCRIBED FOR RANGE BOMBING WITH TOLERANCE

COMPONENTS AND WEIGHTS

COMPONENTS		WEIGHT (lb)	REMARKS
BODY ASSEMBLY	BODY	493.	AS GIVEN ON DRAWING INCLUDING SUSPENSION LUGS REAR CAP, FIN LOCK NUT, AND FUZE SEAT LINER
	ADAPTER-BOOSTER, M102	1.37	AS GIVEN ON DRAWING
	BURSTING CHARGE	618.	AS GIVEN ON DRAWING 50/50 AMATOL INCLUDING SURROUNDS AND AUXILIARY BOOSTERS
	COMPLETE AS LOADED	1112.4	AS GIVEN ON DRAWING
	" " "	1085 ± 15	PRESCRIBED FOR RANGE BOMBING
FIN ASSEMBLY		22.5	STEEL ALUMINUM-9.1 LB.
FUZE, NOSE, M103		4.	AS GIVEN ON DRAWING
FUZE, TAIL, M106		2.4	AS GIVEN ON DRAWING
COMPLETE AS DROPPED		1141.3	AS GIVEN ON DRAWING
" " "	STEEL FINS	1115.4 σ=6.15	MEAN FROM RANGE BOMBING ALUMINUM FINS-1104.9 σ=7.33

EXPECTED MAXIMUM VARIATION IN WEIGHT AS LOADED = ± 19.52 LB.

RATIO, WEIGHT OF BURSTING CHARGE: WEIGHT AS DROPPED = 0.54

EXPERIMENTAL DESIGNATION: STANDARDIZED BY: OCM

PREPARED IN BAL. RES. LAB. A.P.G.

KS-126

	m Weight Complete as Dropped lb.	$\bar{x}$ Distance of Center of Gravity from Nose in.	I_L Moment of Inertia about Longitudinal Axis lb.ft.^{2}	I_T Moment of Inertia about Transverse Axis through Center of Gravity lb.ft.^{2}
Aluminum Fins				
Mean	1104.9	26.56	399.4	1799
Standard Deviation	7.33	0.20	4.6	26
Maximum	1114.9	26.90	404.0	1846
Minimum	1088.9	26.25	388.2	1753
Number of Bombs	18	7	18	18
Steel Fins				
Mean	1115.4	26.84	399.8	1901
Standard Deviation	6.15	0.24	4.0	23
Maximum	1126.9	27.27	410.0	1936
Minimum	1106.1	26.43	394.6	1854
Number of Bombs	14	14	14	14

These statistics refer to all bombs for which a ballistic coefficient with respect to any element was obtained. The actual variations in weight of these bombs do not affect their flight characteristics sufficiently to cause a variation in ballistic coefficient large enough to be detected by the methods for estimating the ballistic coefficient which were used in the reduction of field data. The variation in center of gravity position and moments of inertia would, if sufficiently in excess of that for the present bombs, affect the yaw of the bombs and thereby the dispersion in the elements range, time of flight and trail. The small dispersion of the mechanical constants for these bombs indicates the efficacy of the method of loading described in this report.[1]

[1] A more complete description of the method followed in controlling the mechanical constants is given in Ballistic Research Laboratory Report No. 190: "The Computation of the Mechanical Constants of Bombs."

The center of gravity positions of the bombs summarized above were measured with fins and fuzes. However, the other eleven bombs with aluminum fins had their center of gravity positions measured without fins and fuzes. The following bombs had their center of gravity positions measured without fins and fuzes.

Program Group Serial Number	Date of Release Run Number	Distance of Center of Gravity from Nose in.
KS-126--8	8/19/38-3	26.51
10	5	26.46
9	6	25.82
11	8/22/38-2	26.44
12	8/23/38-2	26.49
13	8/29/38-1	26.41
14	5/24/39-1	26.34
15	2	26.51
16	3	26.50
17	4	26.50
18	5	26.47

V. Description of the Range Bombing

The bombs in this range bombing program were dropped from the B-18, the B-18A, and the B-17B airplanes at a target anchored in Bush River in such a position that the release points were in the fields of view of the Vertical and Oblique Cameras Obscura. The direction of the approach to the release point on all runs was from southeast to northwest within 11°.

On all approaches on which bombs were dropped horizontal flight was maintained as nearly as possible. In all cases with the B-18A and the B-17B airplanes piloting was done by means of the automatic flight control equipment. In all cases with the B-18 airplane piloting was done by manual control.

In these airplanes the bomb racks are so arranged that the longitudinal axis of the bomb is nearly parallel to the thrust line of the airplane, Hence the initial yaw of the bomb in the vertical plane is nearly equal to the angle of attack of the airplane.

On all approaches with both the B-18 and the B-18A airplanes, the bombs were carried in the rear bank of the bomb racks. The center line of this rack is 12.8 feet to the rear of the point formed by the junction of the front edge of the wing with the fuse-

lage of the airplane, this junction being the point on the airplane plotted in the cameras obscura. The corresponding distance in the B-17B is 6.4 feet.[1]

All bombs were dropped according to the current standard practice of the Air Corps, using the current standard bomb sight and a target in Bush River as an aiming point. The results of this range bombing are shown in Appendix B. For the purpose of this report, the displacement of the center of impact with respect to the target is of no special significance. The dispersion about the center of impact and other data summarized in Appendix B are, however, of considerable interest.

The bombs dropped were divided into groups and the endeavor was made to have the altitude and air speed within the group approximate as nearly as possible to certain specified values. These values were described as the standard altitude and the standard air speed.[2]

The number of bombs in each group and the standard altitude and standard air speed for each group are given in Appendix D. The reasons for the selection of these standard altitudes and air speeds are given in Sections VI and IX of this report.

The range bombing was conducted by the following:

Pilots:

Capt. D. W. Watkins, A.C.
Capt. M. J. Lee, A.C.
1st Lt. L. H. Tull, A.C.
1st Lt. R. Billings, A.C.
1st Lt. G. Hatcher, A.C.
1st Lt. M. Cooper, A.C.
1st Lt. H. Estes, A.C.
W.O., J. A. Lee, Sr.
W.O., S. C. Smink

Bombardiers:

Capt. C. S. Thorpe, A.C.
1st Lt. M. F.Summerfelt, A.C.
W.O., S. C. Smink

[1] The effect of bomb bay release position on the estimated values of the ballistic coefficients is discussed in Ballistic Research Laboratory Report No. 136: "First Progress Report: On the Method of Reduction of Observations on the Elements of Bomb Trajectories."

[2] Compare the usage of these terms for statistical purposes in Sections VIII and IX of this report.

Proof Officers:

Lt. Col. K. F. Adamson, O.D.
Capt. J. H. Weber, O.D.
Capt. J. G. Shinkle, O.D.
1st Lt. J. A. Barclay, O.D.
1st Lt. J. D. Armitage, O.D.

VI. Ground Observations

The primary ground observational equipment employed was the Camera Obscura Installation.[1] The position of the aircraft in space and its components of velocity were fundamental data obtained by reduction of observations made with this equipment.

The field data for determinations of times of flight were secured by the chronograph installation housed in the Vertical Camera Obscura. The instants of release and impact were recorded by this chronograph-hydrophone system which has been in use in the present form since 1937.[2] In addition the field data for determination of the time of flight of 1 bomb were obtained by the Western Electric Camera Clock. The camera photographs the impact of the bomb on Bush River and the clock face within the camera at the same instant. The clock in the camera is started by the same radio release signal that is recorded by the chronograph-hydrophone system cited above. The rate of the camera at this time was approximately 150 frames per second.

The coordinates of the impacts referred to the camera coordinate system were obtained by the ground observers by means of azimuth instruments on three towers along the shore of Bush River and were furnished to the Bombing Unit of the

[1] A basic description of the Camera Obscura Installation is given in the "First, Second and Third Progress Reports on Bomb Trajectory Study by the Camera Obscura Method" by Frank Short, F. V. Ludden and S. P. Willan. The equipment has been extensively modified and improved during 1938 and the current equipment and its accuracy are described in Ballistic Research Laboratory Report No. 144: "First Progress Report: On the Accuracy of the Camera Obscura Installation for Obtaining the Initial Data of Bomb Ballistics."

[2] The calibration of this system and the measurement of the systematic errors to which it is subject were carried out in 1938 and are described in Ballistic Research Laboratory Report No. 130: "On the Measurement of the Time of Flight of Bombs." The absolute accuracy and internal precision of the method in actual practice has been determined recently and the results are given in Ballistic Research Laboratory Report No. 211: "Comparsion of Measures of the Time of Flight of Bombs by the Camera Obscura Chronograph and the Western Electric Clock."

Ballistic Research Laboratory. The ground observers also provided the dispersion data with reference to the target and the reduced meteorological data for securing corrections to the elements tabulated in the bombardier's approximate bombing tables. The latter results are graphically summarized in Appendix B, "Primary Results of Range Bombing."

The field data necessary for the reduction of the effects of non-standard meteorological conditions were obtained from two sources. The data secured by the camera observers were the coordinates on the camera plotting boards of smoke puffs at regular time intervals for a series of altitudes, to be used in obtaining ballistic winds; the velocity and the direction of the wind at the earth's surface; and the temperature, the relative humidity and the barometric pressure of the air at the earth's surface. The data secured by the Range Observation Section observers were the spatial positions of a balloon at regular time intervals, and the velocity and direction of the wind at the earth's surface. The temperature and barometric pressure at a series of altitudes were obtained from the bombing flight records of the bombardier. These data were partially reduced by the Range Observation Section and were furnished to the Bombing Unit in the form of tables of:

(1) The actual wind components at a series of altitudes, and
(2) The density of the air at a series of altitudes relative to standard ordnance air density structure.

The actual wind components were taken along a fixed line of known azimuth in the bombing lane, with the sign positive when taken along the direction of flight and positive when taken to the right. The actual wind components and the densities were obtained as near to the time the bombs were dropped as was practicable.

Field data on range bombing with the Bomb, Demolition, 1100-lb., M33 for the bombing tables, BT-1100-A-2, were obtained from the program carried out between June 6, 1938 and May 24, 1939. This included range bombing at 2,000, 5,000, 10,000 and 15,000 foot altitudes. The advance of ballistic theory and increased accuracy of measurement during 1938 and 1939 showed that better results can be obtained from groupings at the maximum obtainable altitude of release, a central altitude and a low altitude. Therefore, between July 6, 1940 and November 20, 1940, range bombing was carried out at 10,000 and 25,000 foot altitudes in accordance with the program outlined in the 2nd Ind. to file 00 471.3/1764. These two altitude groups with the four altitude groups used as the basis for the bombing tables, BT-1100-A-2, comprised the range bombing data for the bombing tables, BT-1100-A-3. However the 15,000 foot altitude group

was given a weight of zero. This was done because the bombs in this group were equipped with aluminum fins and it was found, as the result of stability tests at the Proving Ground, that the M33 bombs so equipped were unstable in flight when dropped from this altitude.[1] Field data for both range and time of flight were obtained and trail determinations were made wherever possible. A total of 32 ranges,[2] 28 times of flight and 27 trails was obtained.

VII. Reduction of Field Data

The data secured by the ground observers at the cameras were utilized to obtain the position and velocity of the airplane at the instant of release. The data secured by the ground observers at the azimuth instruments were utilized to obtain the positions of impact of the bombs. The time intervals obtained from the chronograph strip were employed to determine the uncorrected interval between release and impact. The time intervals from the Western Electric Camera film were likewise utilized. These data were then corrected for instrumental errors.[3]

VIII. Determination of Ballistic Coefficient

The reduction of field data furnished values of range and time of flight corresponding to a certain set of known values of altitude and air speed, but containing the effects of departures from standard ballistic table conditions.[4] The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail is discussed very briefly in Ballistic Research Laboratory Report No. 191.[5] The

[1] As a result of these stability tests steel fins were classified as standard components for all demolition bombs.

[2] On October 22, 1940, Run No. 3, KS-126-6, the measured range was greater than the range in vacuo which indicated a probable lag in bomb rack operation. It was therefore not included in the mean.

[3] The character of these instrumental errors is discussed in Ballistic Research Laboratory Reports No. 144, 130 and 211, previously cited.

[4] Standard ballistic table conditions and standard bombing table conditions are discussed and compared in Ballistic Research Laboratory Report No. 145: "On the Theory of Motion of the Bomb."

[5] The method of reduction of field data in order to obtain ballistic coefficients with respect to range, time of flight and trail has undergone considerable evolution. The reports from which the present methods were developed include: Ballistic Research Laboratory File E-IV-3, "Explanations and Comparisons of the Camera Obscura Methods of Computation"; "Computation of Firing Tables for the U.S. Army"; and Ballistic Research Laboratory Report No. 136, previously cited.

computation of the ballistic coefficients is carried out by means of a Bomb Ballistic Reduction Table which was prepared in the Ballistic Research Laboratory.[1]

In accordance with the principles remarked above the ballistic coefficients corresponding to the ranges, times of flight and trails were then deduced for each individual bomb. From these coefficients the ranges, times of flight and trails were then computed for the standard altitude and standard air speed of the group to which the bomb belonged. These are called the "standard ranges", the "standard times of flight" and the "standard trails", or in general, the "standard elements" and are given in Appendix C together with the corresponding ballistic coefficients. This appendix also lists the program, the group, the serial number stamped on the bomb, the date of release and the run number, the last two providing for comparison with Appendices A and B.

The standard elements and the ballistic coefficients corresponding thereto contain the effects of certain unknown instrumental inaccuracies and of certain departures from standard bombing table conditions which it was not feasible to remove in advance. However, the effects of these sources of dispersion were partially removed by the process used for construction of the bombing tables.

IX. Construction of Tables

The experimental data from which the ballistic coefficients with respect to range, time of flight and trail were determined fell into 5 altitude groups. The groups were for standard altitudes of 2,000, 5,000, 10,000, 15,000 and 25,000 feet. The dependence of the ballistic coefficients upon altitude of release was determined from these 5 groups.

The mean standard elements for a standard true air speed and altitude were determined for each altitude group. The mean standard element is the arithmetic mean of the individual standard elements. The individual standard elements used in computing the mean standard elements had been reduced to the group standard altitude and true air speed. The use of the mean standard elements reduces the influence of the accidental errors in the individual standard elements upon the elements tabulated in the bombing table. The ballistic coefficients corresponding to these mean standard elements were then deduced. The forms of the functional dependence upon altitude of the three ballistic coefficients have been derived theoretically and verified empirically.[2] The lift is the cause mainly responsible for the character of the variation of the ballistic coefficients with

[1] A discussion of the ballistic coefficients corresponding to range, time of flight and trail is given in Ballistic Research Laboratory Report No. 143: "Errors in Trail Resulting from Ignoring Either the Measured Range or the Measured Time of Flight."

[2] The derivation of the form of these relations between the ballistic coefficients and the altitudes of release is discussed in Ballistic Research Laboratory Report No. 145, previously cited.

altitude. The lift is due to the yaw arising from the initial angular velocity of the tangent to the trajectory. The effects of lift are allowed to remain in the ballistic coefficients corresponding to the mean standard elements. The functional relations referred to are:

$$C_{X_y} = \frac{C_{X_\infty}}{1 + \frac{k_X C_{X_\infty}}{\sqrt{Y}}}$$

$$C_{T_y} = \frac{C_{T_\infty}}{1 + \frac{k_T C_{T_\infty}}{\sqrt{Y}}}$$

$$C_{\lambda_y} = \frac{C_{\lambda_\infty}}{1 + \frac{k_\lambda C_{\lambda_\infty}}{\sqrt{Y}}}$$

These curves each contain two empirical quantities k and C_∞. The subscript ∞ refers to the mean effective ballistic coefficient for infinite altitude, and k is a parameter determining the shape of the curve.

A new procedure for estimating the values of C_{X_∞}, C_{T_∞}, C_{λ_∞} k_X, k_T, and k_λ was in use when these bombing tables were computed. The first modification consisted in changing the method of weighting the points. The earlier procedure assigned weights proportional to the product of the number of bombs in the group and a factor dependent upon a priori considerations of the probable accuracy of the determination. No account was taken of the fact that the probable error of bombing is an increasing function of the altitude of release. In consequence, unduly great weight was attached to the groups of bombs at the high altitude. The new procedure for range and trail used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination and the reciprocal of altitude of release. The new procedure for the time of flight used weights proportional to the product of the number of bombs in the group, a factor dependent upon a priori considerations of the probable accuracy of the determination, the reciprocal of the altitude and the standard true air speed. The second modification consisted in a change of the functions to be minimized. The function

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minimized in the earlier procedure was the sum of the weighted squares of the residuals of the reciprocal ballistic coefficients. The function minimized in the new procedure was the sum of the weighted squares of the residual differences between the mean standard elements and those elements which would result from the use of the bombing tables.[1] This modification has resulted in much smaller probable ballistic errors for bombing tables.[2] A considerable improvement in the accuracy of the bombing tables has resulted therefrom. The improvement is shown by the magnitude, as compared with earlier bombing tables, of the differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables.

The values C_{X_∞}, C_{T_∞}, C_{λ_∞}, k_X, k_T and k_λ were deduced by the new procedure described above. The values were:

$$C_{X_\infty} = 2.527 \; ; \quad C_{T_\infty} = 5.145 \; ; \quad C_{\lambda_\infty} = 3.405$$

$$k_X = -16.148 \; ; \quad k_T = 2.321 \; ; \quad k_\lambda = -6.963$$

The observed and fitted ballistic coefficients are compared in Tables 1, 2 and 3 of Appendix D. The relations between the fitted ballistic coefficients and the altitudes of release are shown in Plots I, II and III of Appendix D. The fitting provides for obtaining the ballistic coefficient for any altitude of release. The actual points on the plots in Appendix D are shown by dots and their probable errors by horizontal strokes placed on the sides of the dots. The computed C : Y relations are shown by heavy lines. The dotted lines furnish the probable error of forecast bands. The band is determined by addition and substraction of the probable error of the computed C : Y relation from the curve.

The construction of the Table of DS followed general instructions given in file 00 063.2/4524(Confidential). The trail angles, times of flight and dropping angles were obtained by interpolation with the fitted C : Y relations in the Bomb Ballistic Auxiliary Tables, computed in the Ballistic Research

[1] The new procedure is described more completely in Ballistic Research Laboratory Report No. 136, previously cited.

[2] The ballistic error is a term originally used by British ballisticians to denote the difference between the bombing table range and the mean standard range for the same conditions. The ballistic error is denoted by $X-X_f$ in this report.

Laboratory. These tables give trail angles, times of flight and dropping angles as functions of the altitude of release, Y; the calibrated indicated air speed, V, or true ground speed, V_g; and the reciprocal ballistic coefficient, $\frac{1}{C}$. The intervals of the arguments used in the Bomb Ballistic Auxiliary Tables are the same as those used in the present series of abridged bombing tables. The small differences between the observed mean standard ranges, times of flight and trails, and those elements which would result from employment of these tables are shown in the columns $X-X_f$, $T-T_f$ and $\lambda-\lambda_f$ given in Tables 1, 2 and 3 of Appendix D. These differences are compared with the probable errors of the observed mean standard elements in Plots IV, V and VI of Appendix D. The importance of employment of the fitted C_{X_y} : Y, C_{T_y} : Y and C_{λ_y} : Y curves is shown by the small magnitude of these differences.

The range of arguments included in these bombing tables, BT-1100-A-3, is indicated in the table below:

Element	Speed mi./hr.		Altitude ft.	
	Minimum	Maximum	Minimum	Maximum
Trail Angle (Calibrated Indicated Air Speed)	100	250	1800	35000
DS (Calibrated Indicated Air Speed)	160		1200	36000
Time of Flight (Calibrated Indicated Air Speed)	160		1000	36000
Dropping Angle (Ground Speed)	100	250	100	10000
Provisional				
Trail Angle (Calibrated Indicated Air Speed)	200	400	1800	35000
Time of Flight (Calibrated Indicated Air Speed)	160	320	1000	35000

E. S. Martin

E. W. Crump

Appendix A

Mechanical Constants of Bombs

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Appendix A

Mechanical Constants of Bombs [1]

Program Group Serial Number	Date of Release Run Number	m Weight Complete as Dropped lb.	$\bar{x}$ Distance of Center of Gravity from Nose in.	I_L Moment of Inertia about Longitudinal Axis lb.ft.^{2}	I_T Moment of Inertia about Transverse Axis through Center of Gravity lb.ft.^{2}
KS-126--2	6/6/38--2	1092.0	26.55	401.0	1771
3	3	1105.0	26.90	403.1	1813
1	6/14/38-1	1110.5	26.40	403.9	1834
4	2	1098.0	26.76	403.6	1801
5	6/30/38-1	1105.0	26.55	402.2	1812
6	2	1110.0	26.48	403.4	1821
8	8/19/38-3	1101.9		400.5	1762
7	4	1094.0	26.25	399.7	1765
10	5	1100.9		402.3	1813
9	6	1109.9		403.6	1817
11	8/22/38-2	1114.0		404.0	1846
12	8/23/38-2	1107.9		399.3	1753
13	8/29/38-1	1106.9		397.6	1775
14	5/24/39-1	1105.9		392.9	1798
15	2	1088.9		388.2	1779
16	3	1114.9		396.4	1822
17	4	1109.9		392.2	1790
18	5	1111.9		394.9	1812
1	7/6/40--1	1113.0	26.70	398.7	1916
2	2	1126.9	27.17	394.9	1877
4	7/10/40-1	1117.8	27.17	403.3	1923
3	2	1119.3	27.27	397.5	1874
8	10/22/40-1	1110.6	26.76	397.5	1909
7	2	1115.6	26.56	400.8	1920
6	3	1113.9	27.03	399.0	1907
5	4	1124.8	26.43	402.2	1936
11	11/4/40-1	1113.7	26.89	402.2	1878
12	2	1106.1	26.75	394.6	1854
9	3	1111.5	26.69	398.9	1903
10	4	1123.6	26.69	410.0	1920
13	11/20/40-1	1107.3	26.90	394.7	1882
14	2	1111.0	26.72	402.7	1912

[1] Bombs dropped previous to 1940 had aluminum fins; bombs dropped after 1939 had steel fins.

Appendix B

Primary Results of Range Bombing

RESULTS OF RANGE BOMBING NO. 16

JUNE 6, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

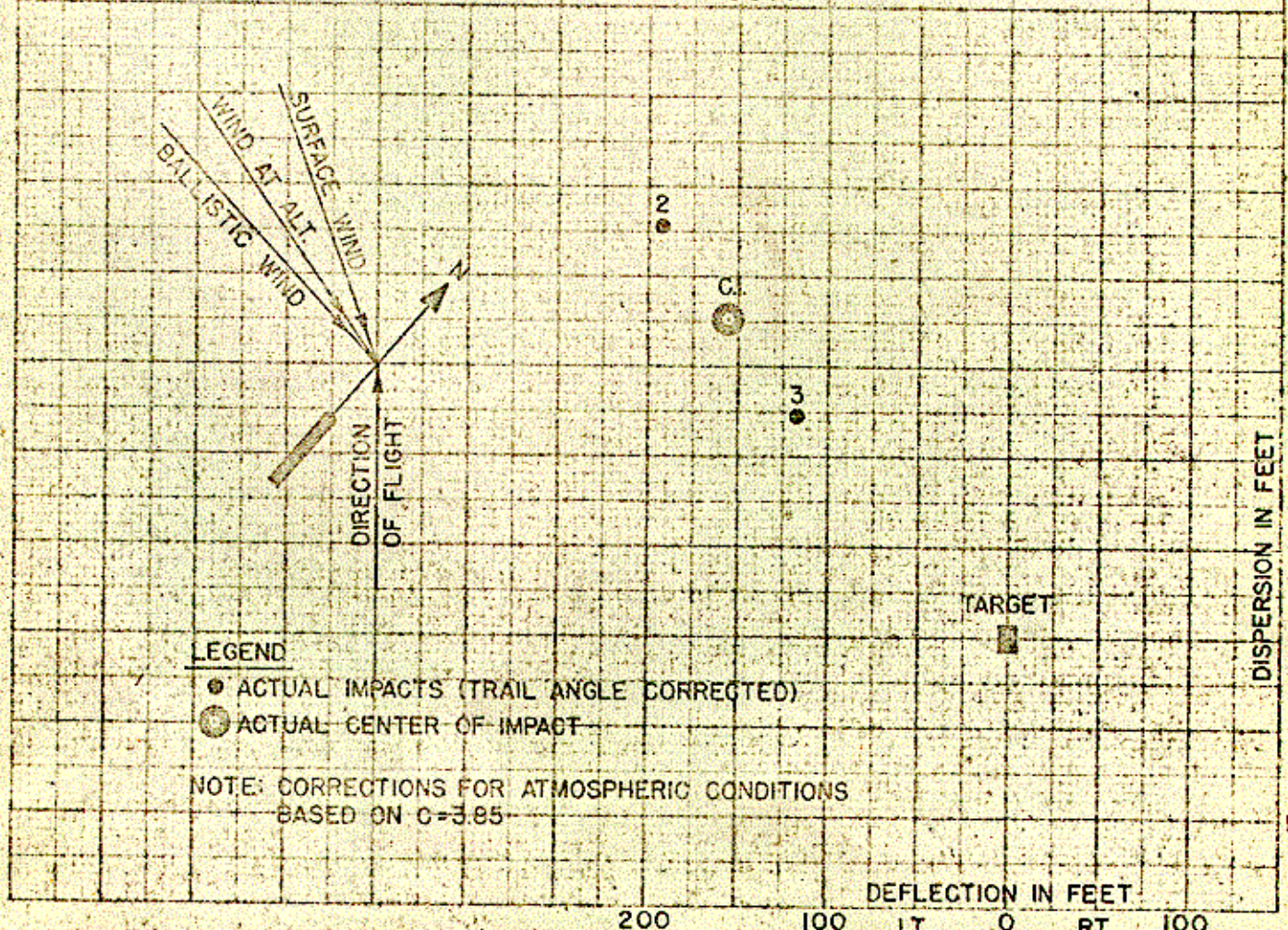
PILOT: W. O. J. A. LEE — BOMBARDIER: SGT. S. C. SMINK

SKY: — AIR: — TRAIL AND D.S. BASED ON C = 3.54

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT	ALTITUDE GRND. OBS. FT	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GRND. OBS. M/HR	GRND. SPEED GRND OBS. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN	CLIMB-GLIDE GRND. OBS. FT/MIN	DEVIATIONS FROM TARGET RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT	DEFLECTION LEFT FT.
1													
2	2:41	10490	10499	134	157.0	156.1	123.7		+12.8	228			192
3	3:11	10465	10461	135	158.2	156.5	119.5		-39.3	123			117
4													
5													
6													
DIFFERENTIAL BALLISTIC WIND M/HR.										CENTER OF IMPACT	176		155
RANGE: -6.4				CROSS: -1.3						MEAN DEVIATION	53		38

		TIME 12:53	TIME 3:21
WIND	SURFACE, VELOCITY (M/HR)	17.0	17.0
	AT ALTITUDE, VELOCITY "	36.9	38.1
	BALLISTIC, VELOCITY "	32.4	31.0
	BALLISTIC, AZIMUTH (TO)	277.5°	277.6°
DENSITY	AT SURFACE	0.979	0.972
	BALLISTIC (SURFACE)	0.993	0.988
	BALLISTIC (AIR OBS.)	0.976	0.977

CORRECTIONS USED	MILS IN RANGE	DEFL.
WIND	-1.3	0.2 LT.
DENSITY	-0.6	—
TOTAL	-1.9	0.2 LT.



LEGEND

● ACTUAL IMPACTS (TRAIL ANGLE CORRECTED)

◉ ACTUAL CENTER OF IMPACT

NOTE: CORRECTIONS FOR ATMOSPHERIC CONDITIONS BASED ON C=3.85

RESULTS OF RANGE BOMBING NO. 17

JUNE 14, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

PILOT LT. L. H. TULL — BOMBARDIER: SGT. S. C. SMINK

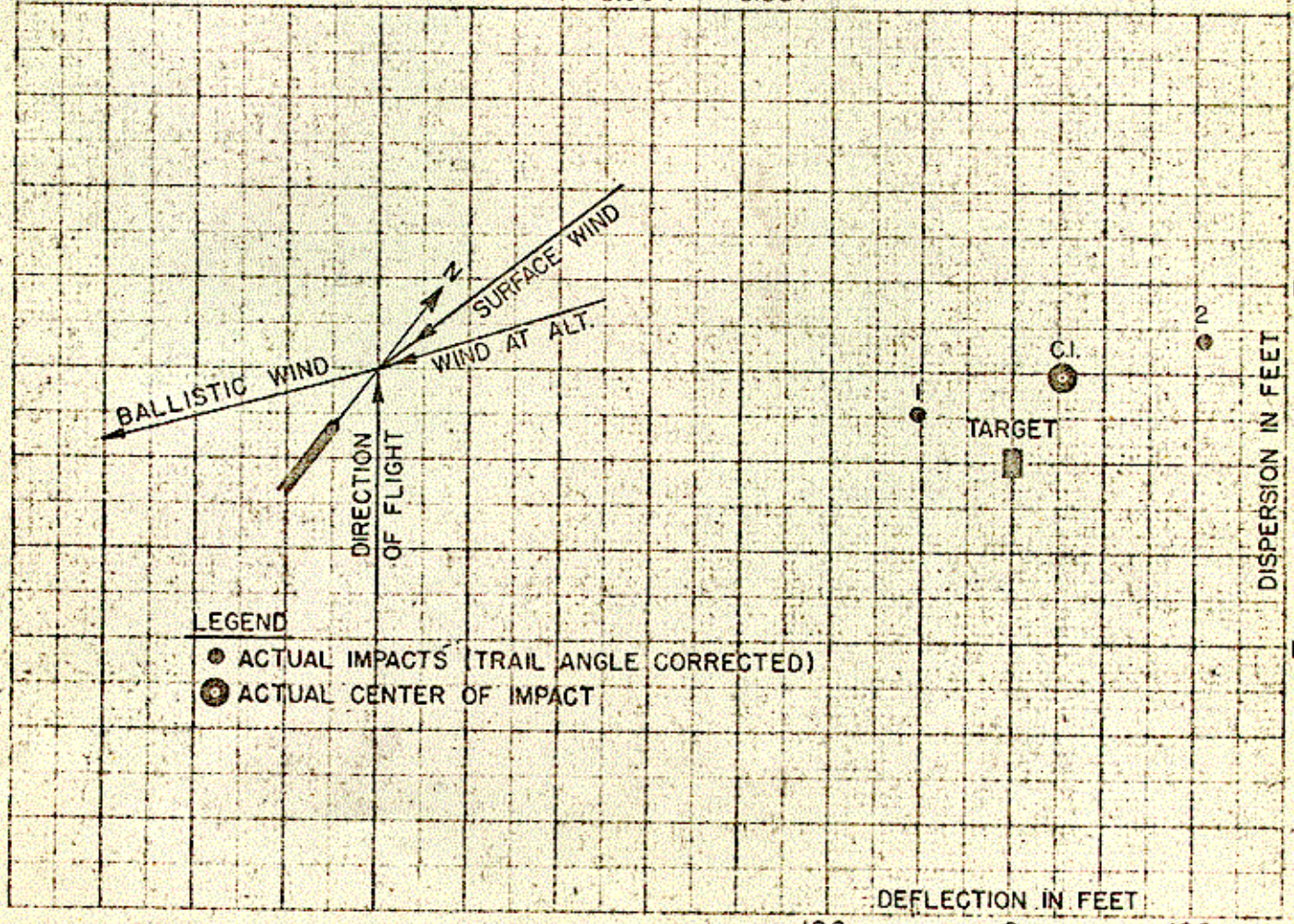
SKY — AIR — TRAIL AND D.S. BASED ON C = 3.54

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS FT	ALTITUDE GRND OBS. FT	AIR SPEED CAL IND M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GRND OBS. M/HR	GRND. SPEED GRND. OBS.. M/HR	CLIMB-GLIDE AIR OBS. FT/MIN.	CLIMB-GLIDE GRND. OBS. FT/MIN.	DEVIATIONS FROM TARGET RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT
1	10:22	10250	10206	133	155.3	155.8	140.7		+25.8	27			51
2	10:58	10390	10338	134	156.8	158.2	142.2		+ 4.1	69		105	
3													
4													
5													
6													
DIFFERENTIAL BALLISTIC WIND M/HR.							CENTER OF IMPACT			48		27	
RANGE: −1.2				CROSS: −2.7			MEAN DEVIATION			21		78	

	TIME	9:23	11:18
WIND	SURFACE VELOCITY (M/HR)	8.0	5.0
	AT ALTITUDE, VELOCITY "	20.7	20.0
	BALLISTIC VELOCITY "	17.8	16.7
	BALLISTIC AZIMUTH (TO)	37.9°	36.0°
DENSITY	AT SURFACE	0.999	0.990
	BALLISTIC (SURFACE)	1.005	1.000
	BALLISTIC (AIR OBS.)	0.994	0.997

CORRECTIONS USED

MILS IN	RANGE	DEFL.
WIND	−0.3	0.4 LT.
DENSITY	+0.1	—
TOTAL	−0.2	0.4 LT.



RESULTS OF RANGE BOMBING NO. 18

JUNE 30, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B18

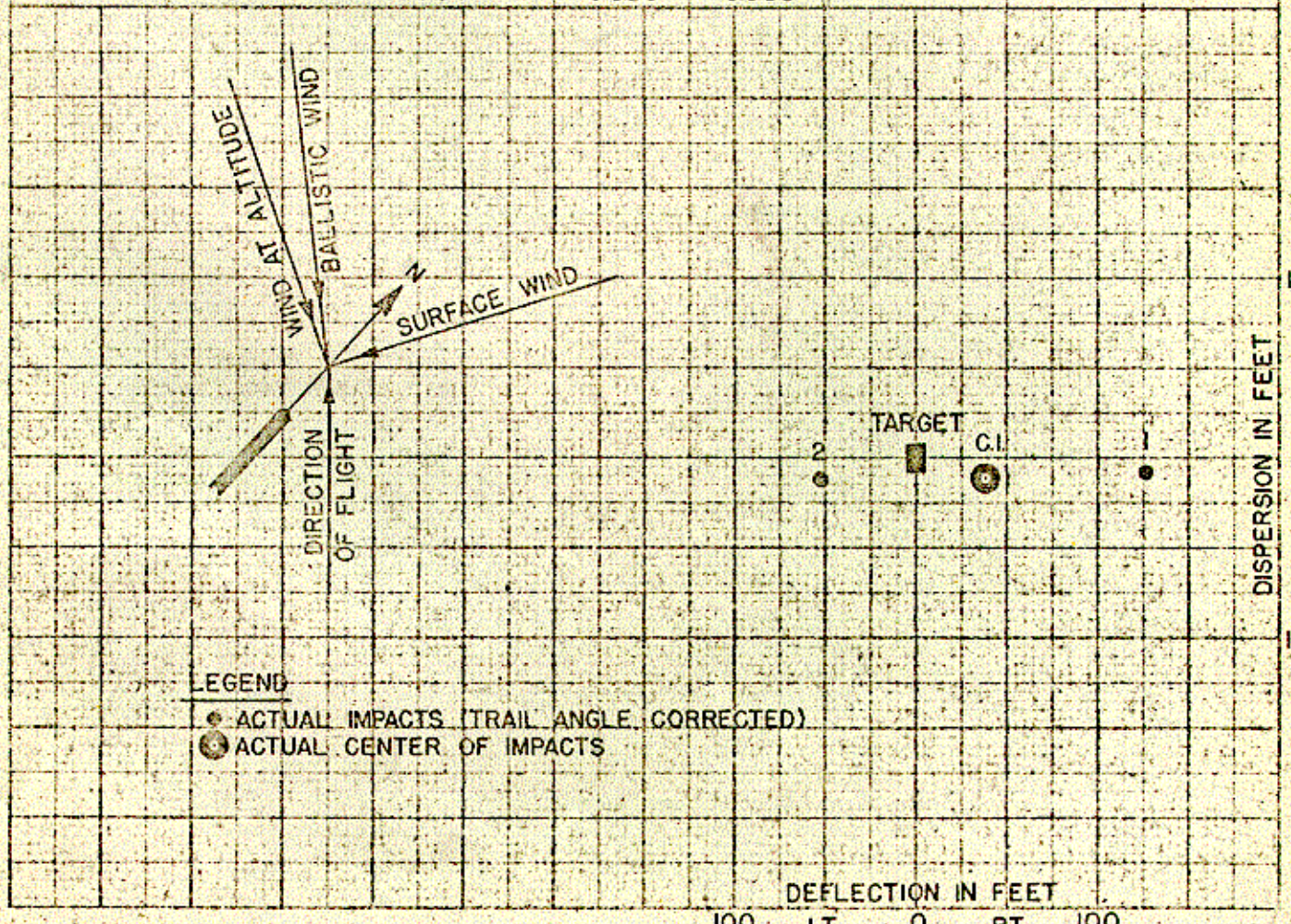
PILOT W.O. J.A. LEE — BOMBARDIER: SGT. S. C. SMINK

SKY — AIR — TRAIL AND D.S. BASED ON C = 3.54

BOMB NO	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GRND OBS. FT	AIR SPEED CAL. IND. M/HR	AIR SPEED TRUE AIR OBS M/HR	AIR SPEED TRUE GRND. OBS. M/HR	GRND. SPEED GRND. OBS. M/HR	CLIMB-GLIDE AIR OBS FT/MIN.	CLIMB-GLIDE GRND. OBS. FT/MIN.	DEVIATIONS FROM TARGET RANGE OVER FT	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:32	10380	10363	134	156.9	158.6	152.0		−0.7		9	126	
2	10:41	10410	10412	133	155.7	153.0	147.5		+0.7		12		51
3													
4													
5													
6													
DIFFERENTIAL BALLISTIC WIND M/HR.							CENTER OF IMPACT				11	38	
RANGE: −1.9			CROSS: +2.4				MEAN DEVIATION				2	89	

	TIME	9:09	11:23
WIND	SURFACE, VELOCITY (M/HR)	7.0	3.0
	AT ALTITUDE, VELOCITY "	10.3	8.8
	BALLISTIC VELOCITY "	8.0	7.8
	BALLISTIC AZIMUTH (TO)	311.5°	288.8°
DENSITY	AT SURFACE	0.996	0.985
	BALLISTIC (SURFACE)	1.004	0.997
	BALLISTIC (AIR OBS.)	0.988	0.986

CORRECTIONS USED	MILS IN RANGE	DEFL.
WIND	−0.4	0.4 RT.
DENSITY	0	—
TOTAL	−0.4	0.4 RT.



RESULTS OF RANGE BOMBING NO. 28

AUG. 19, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE 6.18

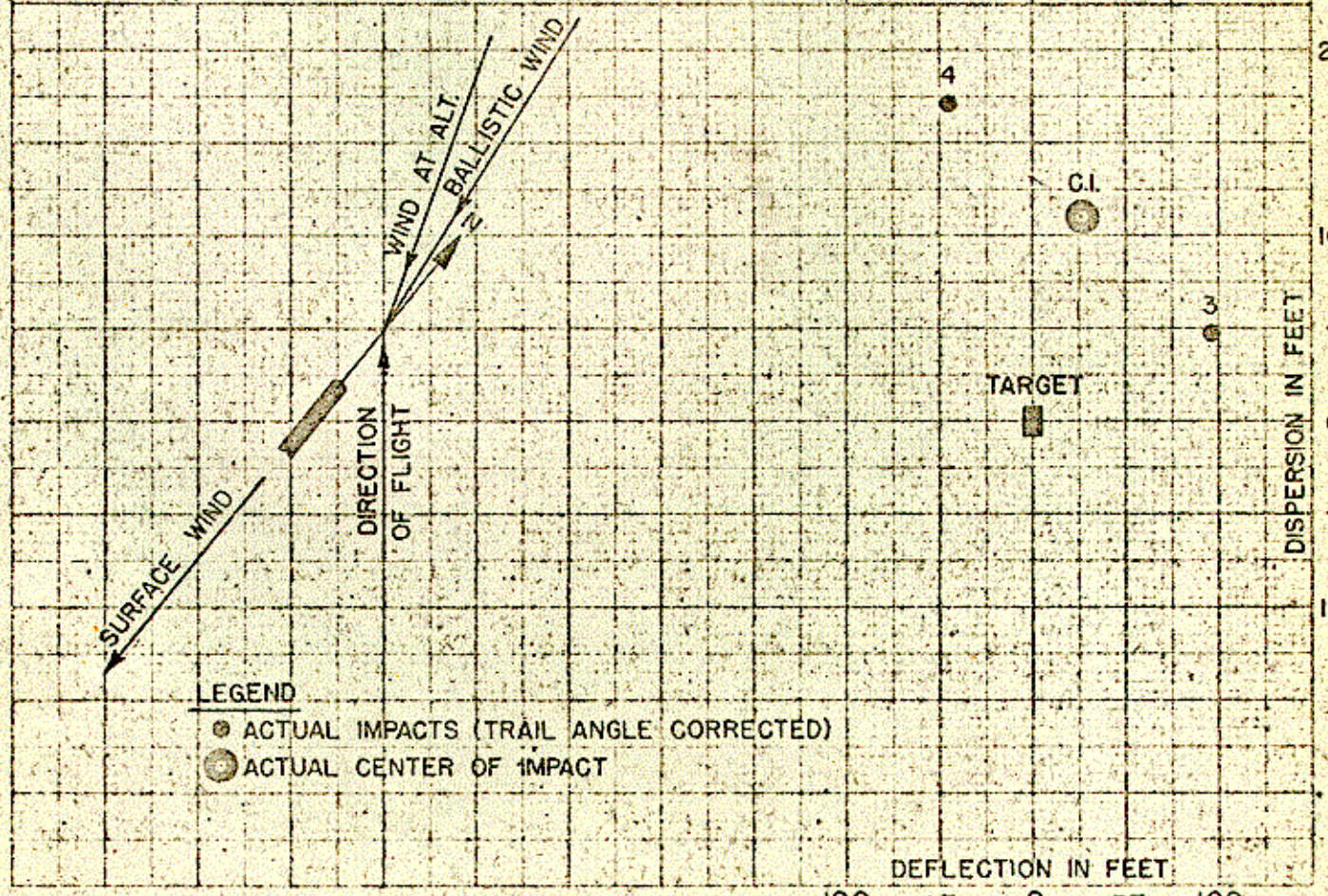
PILOT: W. O. J. A. LEE — BOMBARDIER: SGT. S. C. SMINK

SKY: — AIR: — TRAIL AND D.S. BASED ON C = 4.04

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND. OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR.	AIR SPEED TRUE GR'ND OBS. M/HR.	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN.	HOR. RANGE FT.	DEVIATIONS FROM TARGET RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1													
2													
3	1:50	15870	15791	123	157.8	146.0	135.8	−198.3	5919	48		96	
4	1:55	15880	15836	123	157.9	146.8	136.5	−194.9	6104	176			45
5													
6													
									CENTER OF IMPACT	110		26	
									MEAN DEVIATION	62		71	

		TIME	12:35	2:43
WIND VELOCITY M.P.H.	SURFACE		11.0	10.0
	AT ALTITUDE		11.7	12.7
	BALLISTIC		11.2	12.6
	DIFFERENTIAL BALLISTIC	RANGE	−1.7	−1.1
		CROSS	+1.7	+1.9
DENSITY	AT SURFACE		0.969	0.966
	BALLISTIC (SURFACE)		0.994	0.992
	BALLISTIC (AIR OBS.)		0.963	0.962

CORRECTIONS USED	MILS IN RANGE	DEFL.
WIND	− 0.3	0.3 RT.
DENSITY	− 0.9	—
TOTAL	− 1.2	0.3 RT.



RESULTS OF RANGE BOMBING NO. 29

AUG. 19, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

PILOT W. O. J. A. LEE — BOMBARDIER SGT. S. C. SMINK

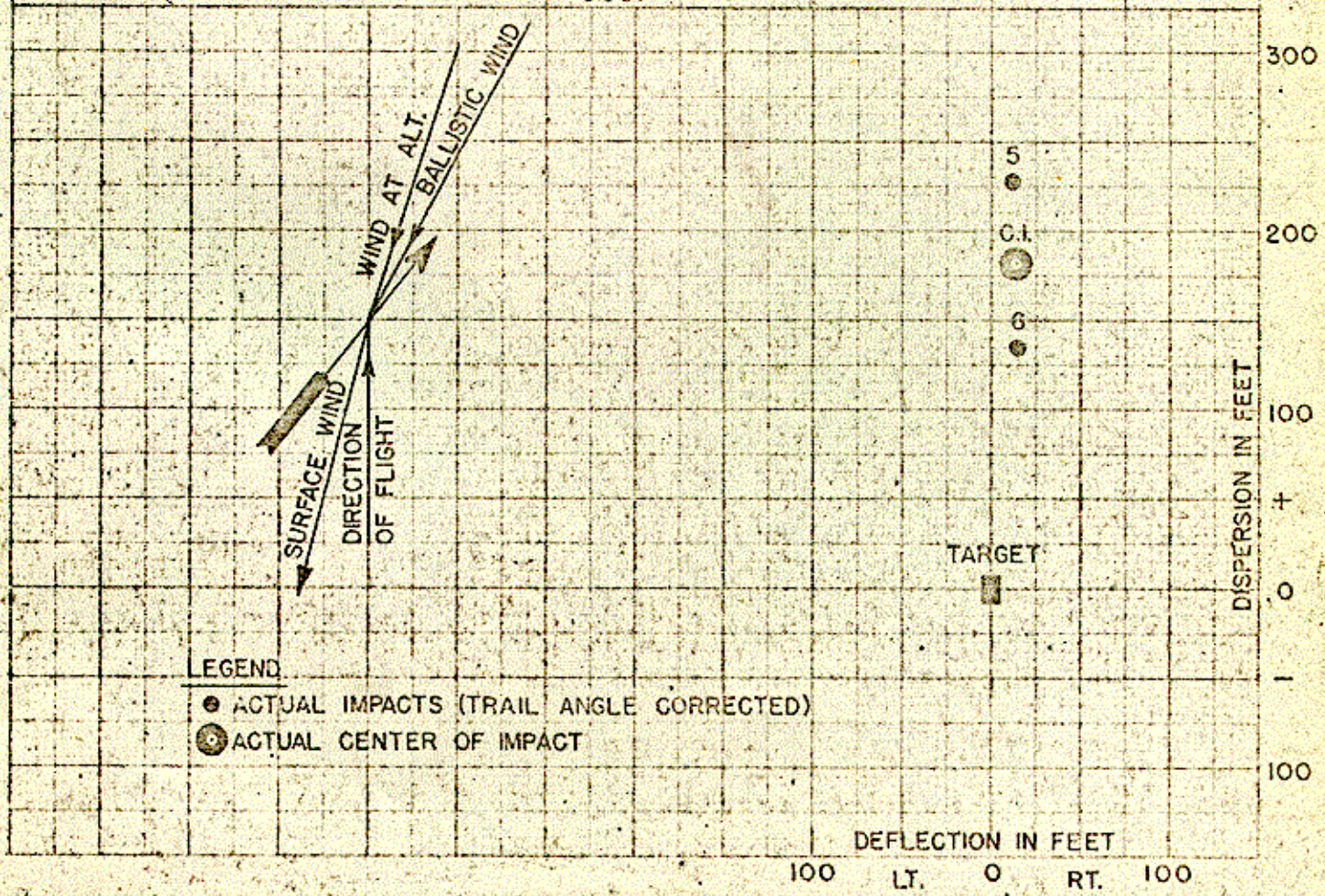
SKY: — AIR: — TRAIL AND O.S. BASED ON G = 4.04

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GRND OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS. M/HR.	AIR SPEED TRUE GRND OBS. M/HR.	GRND SPEED GRND OBS. M/HR.	CLIMB OR GLIDE GRND OBS. FT/MIN.	HOR. RANGE FT.	DEVIATIONS FROM TARGET RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1													
2													
3													
4													
5	4:00	15925	15928	123	158.2	152.1	141.0	-206.2	6359	228		12	
6	4:10	15830	15816	123	157.9	153.2	142.0	-196.6	6357	135		15	
									CENTER OF IMPACT	182		14	
									MEAN DEVIATION	47		2	

TIME		2:43	———
WIND VELOCITY M.P.H.	SURFACE	10.0	
	AT ALTITUDE	12.7	
	BALLISTIC	12.6	
	DIFFERENTIAL BALLISTIC — RANGE	-1.1	
	DIFFERENTIAL BALLISTIC — CROSS	+1.9	
DENSITY	AT SURFACE	0.966	
	BALLISTIC (SURFACE)	0.992	
	BALLISTIC (AIR OBS.)	0.961	

CORRECTIONS USED

MILS IN	RANGE	DEFL.
WIND	— 0.2	0.3 RT.
DENSITY	— 0.9	—
TOTAL	— 1.1	0.3 RT.



RESULTS OF RANGE BOMBING NO. 31

AUG. 22, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

PILOT: CAPT. D. W. WATKINS — BOMBARDIER: SGT. S. C. SMINK

SKY: — AIR: — TRAIL AND D.S. BASED ON C = 4.45

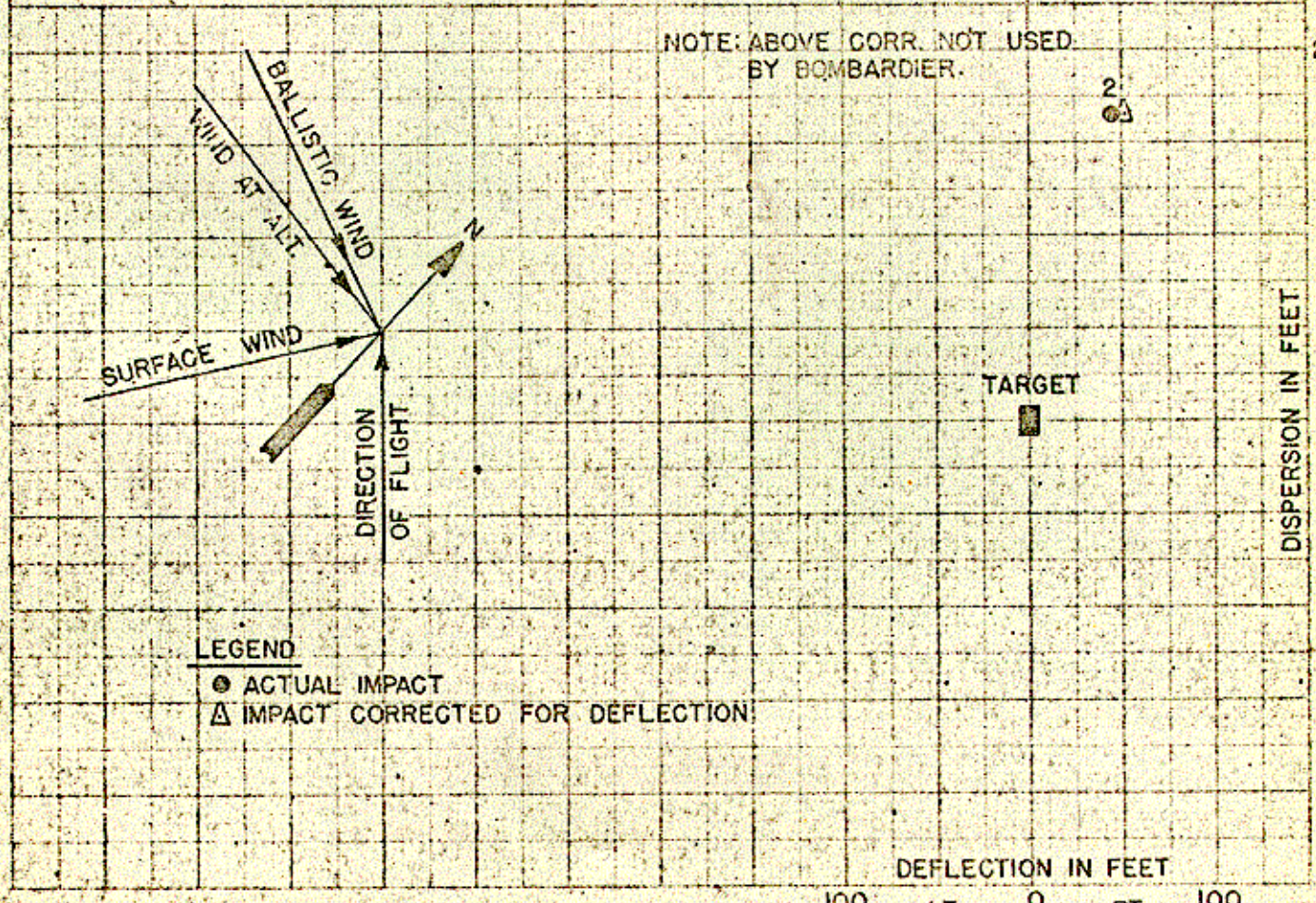
BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL. IND. M/HR.	AIR SPEED TRUE AIR OBS M/HR.	AIR SPEED TRUE GR'ND OBS. M/HR.	GR'ND SPEED GR'ND OBS. M/HR.	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR RANGE FT.	DEVIATIONS FROM TARGET RANGE OVER FT	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1													
2	10:35	5350	5358	128	139.3	140.9	129.0	−25.9	3484	165		45	
3													
4													
5													
6													
CENTER OF IMPACT													
MEAN DEVIATION													

		TIME	9:57	10:58
WIND VELOCITY M.P.H.	SURFACE		8.0	7.0
	AT ALTITUDE		12.5	13.9
	BALLISTIC		10.5	12.3
	DIFFERENTIAL BALLISTIC	RANGE	−0.6	−1.2
		CROSS	+3.1	+2.3
DENSITY	AT SURFACE		0.971	0.965
	BALLISTIC (SURFACE)		0.981	0.977
	BALLISTIC (AIR OBS.)		0.980	0.975

CORRECTIONS

MILS IN	RANGE	DEFL.
WIND	− 0.1	0.4 RT.
DENSITY	− 0.6	—
TOTAL	− 0.7	0.4 RT.

NOTE: ABOVE CORR. NOT USED BY BOMBARDIER.



LEGEND

● ACTUAL IMPACT

△ IMPACT CORRECTED FOR DEFLECTION

RESULTS OF RANGE BOMBING NO. 33

AUG. 23, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

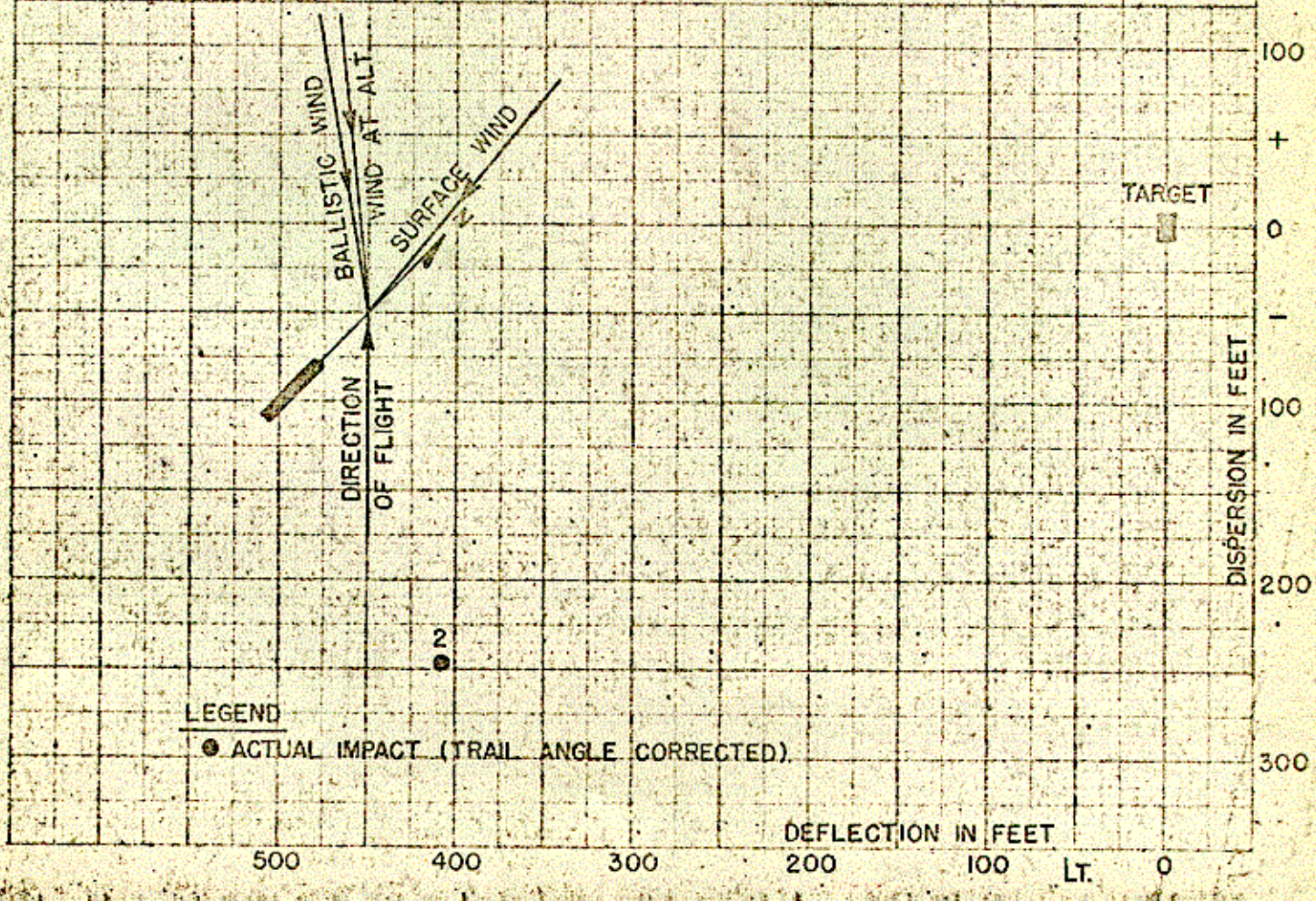
PILOT: CAPT. D. W. WATKINS — BOMBARDIER: SGT. S. C. SMINK

SKY: — AIR: — TRAIL AND O.S. BASED ON C = 4.04

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
										RANGE		DEFLECTION	
		AIR OBS.	GR'ND. OBS.	CAL.	TRUE								
				IND.	AIR OBS.	GR'ND. OBS.	GR'ND OBS.	GR'ND OBS.		OVER	SHORT	RIGHT	LEFT
		FT.	FT.	M/HR	M/HR	M/HR	M/HR	FT/MIN	FT.	FT.	FT.	FT.	FT.
1													
2	10:21	15860	15827	132	169.5	165.8	140.8	+52.8	6158		246		408
3													
4													
5													
6													
CENTER OF IMPACT													
MEAN DEVIATION													

	TIME	8:46	10:55
WIND VELOCITY M.P.H.	SURFACE	3.0	4.0
	AT ALTITUDE	27.1	22.6
	BALLISTIC	24.4	21.7
	DIFFERENTIAL RANGE	−3.0	−0.7
	DIFFERENTIAL CROSS	−1.4	+1.0
DENSITY	AT SURFACE	0.981	0.969
	BALLISTIC (SURFACE)	1.000	0.994
	BALLISTIC (AIR OBS.)	0.964	0.964

CORRECTIONS USED		
MILS IN	RANGE	DEFL.
WIND	− 0.6	0.2 LT.
DENSITY	− 0.5	—
TOTAL	− 1.1	0.2 LT.



RESULTS OF RANGE BOMBING NO. 34

AUG. 29, 1938 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B 18

PILOT: CAPT. D. W. WATKINS — BOMBARDIER: SGT. S. C. SMINK

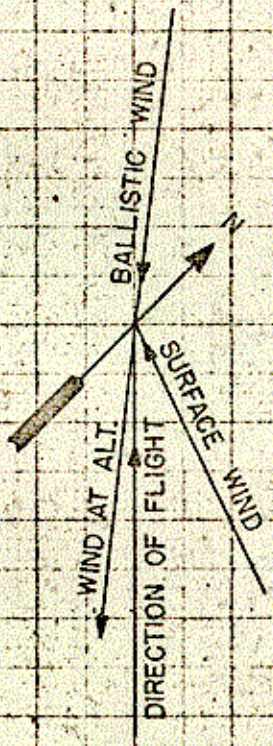
SKY: — AIR: — TRAIL AND D.S. BASED ON C = 4.45

BOMB NO	TIME OF REL.	ALTITUDE		AIR SPEED			GRND SPEED	CLIMB OR GLIDE	HOR RANGE	DEVIATIONS FROM TARGET			
		AIR OBS.	GRND OBS.	CAL.	TRUE					RANGE		DEFLECTION	
				IND.	AIR OBS.	GRND. OBS.	GRND OBS.	GRND OBS.		OVER	SHORT	RIGHT	LEFT
		FT.	FT.	M/HR.	M/HR.	M/HR.	M/HR.	FT/MIN.	FT.	FT.	FT.	FT.	FT.
1	11:20	5200	5175	133	144.3	145.1	142.8	−34.5	3683	87			42
2													
3													
4													
5													
6													
CENTER OF IMPACT													
MEAN DEVIATION													

		TIME	9:25	11:37
WIND VELOCITY M.P.H.	SURFACE		8.0	5.0
	AT ALTITUDE		3.5	0.2
	BALLISTIC		1.1	1.7
	DIFFERENTIAL BALLISTIC	RANGE	−2.5	−1.8
		CROSS	−0.3	+0.5
DENSITY	AT SURFACE		0.982	0.974
	BALLISTIC (SURFACE)		0.990	0.983
	BALLISTIC (AIR OBS.)		0.983	0.991

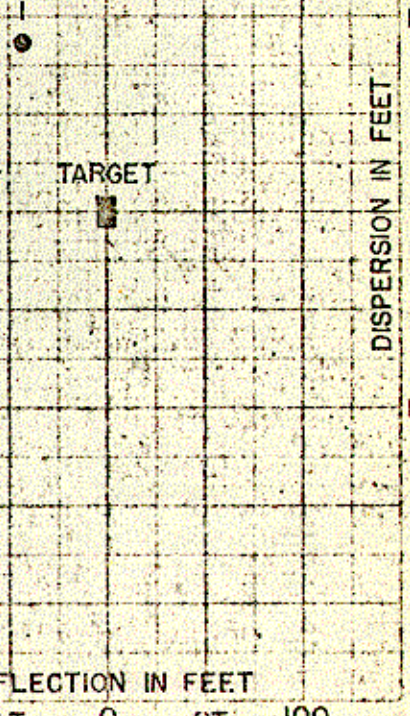
CORRECTIONS		
MILS IN	RANGE	DEFL.
WIND	− 0.4	0
DENSITY	− 0.3	−
TOTAL	− 0.7	0

NOTE: ABOVE CORR. NOT USED BY BOMBARDIER.



LEGEND

● ACTUAL IMPACT



RESULTS OF RANGE BOMBING NO. 66

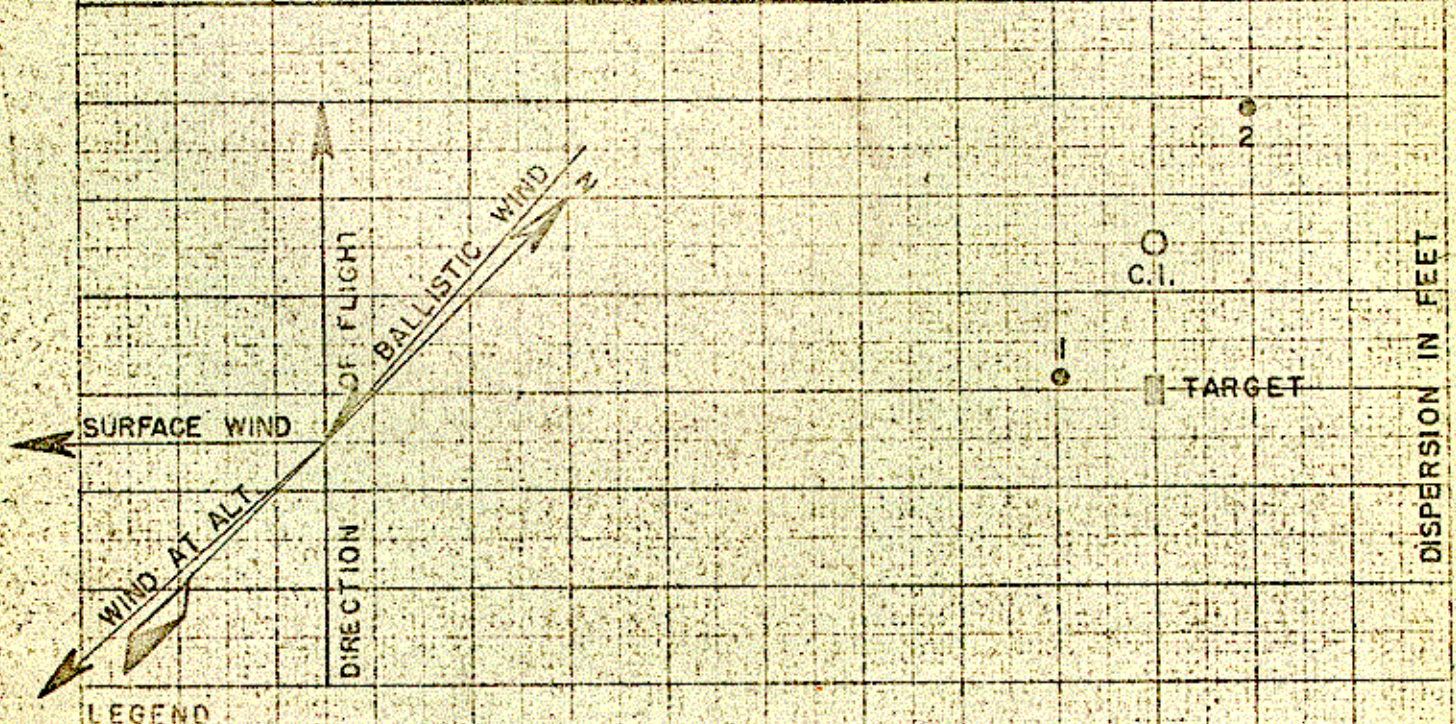
JULY 6, 1940 — 1100 LB DEMOLITION BOMB M33 — AIRPLANE B-18A

PILOT: LT. R. BILLINGS — BOMBARDIER: LT. M. F. SUMMERFELT

SKY: CLEAR — AIR: SMOOTH — TRAIL AND D.S. BASED ON BT-1100-A-2

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
										RANGE		DEFLECTION	
		AIR OBS. FT.	GR'ND OBS. FT.	CAL IND M/HR	TRUE AIR OBS. M/HR	TRUE GR'ND OBS. M/HR	GR'ND OBS. M/HR	GR'ND OBS. FT/MIN	FT.	OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	10:05	10460	10396	140	165.0	166.4	160.0	-130.6	5731	6			48
2	10:15	10440	10397	143	168.5	165.5	159.1	+ 3.7	5809	144		48	
3													
4													
5													
6													
CENTER OF IMPACT										75		0.0	
MEAN DEVIATION										69		48	

		R.O.S.	R.O.S.	CAMERA
TIME		8:00	10:35	10:23
WIND VELOCITY M.P.H.	SURFACE	4.0	5.0	5.0
	AT ALTITUDE	17.3	13.9	16.0
	BALLISTIC RANGE WIND	- 8.8		- 7.8
	BALLISTIC CROSS WIND	- 8.0		- 10.1
DENSITY	AT SURFACE	0.989		0.968
	BALLISTIC (SURFACE)	1.000		0.986
	BALLISTIC (AIR OBS.)	1.004		



RESULTS OF RANGE BOMBING NO. 68

JULY 10, 1940 — 1100 LB DEMOLITION BOMB M33 — AIRPLANE B-17-B

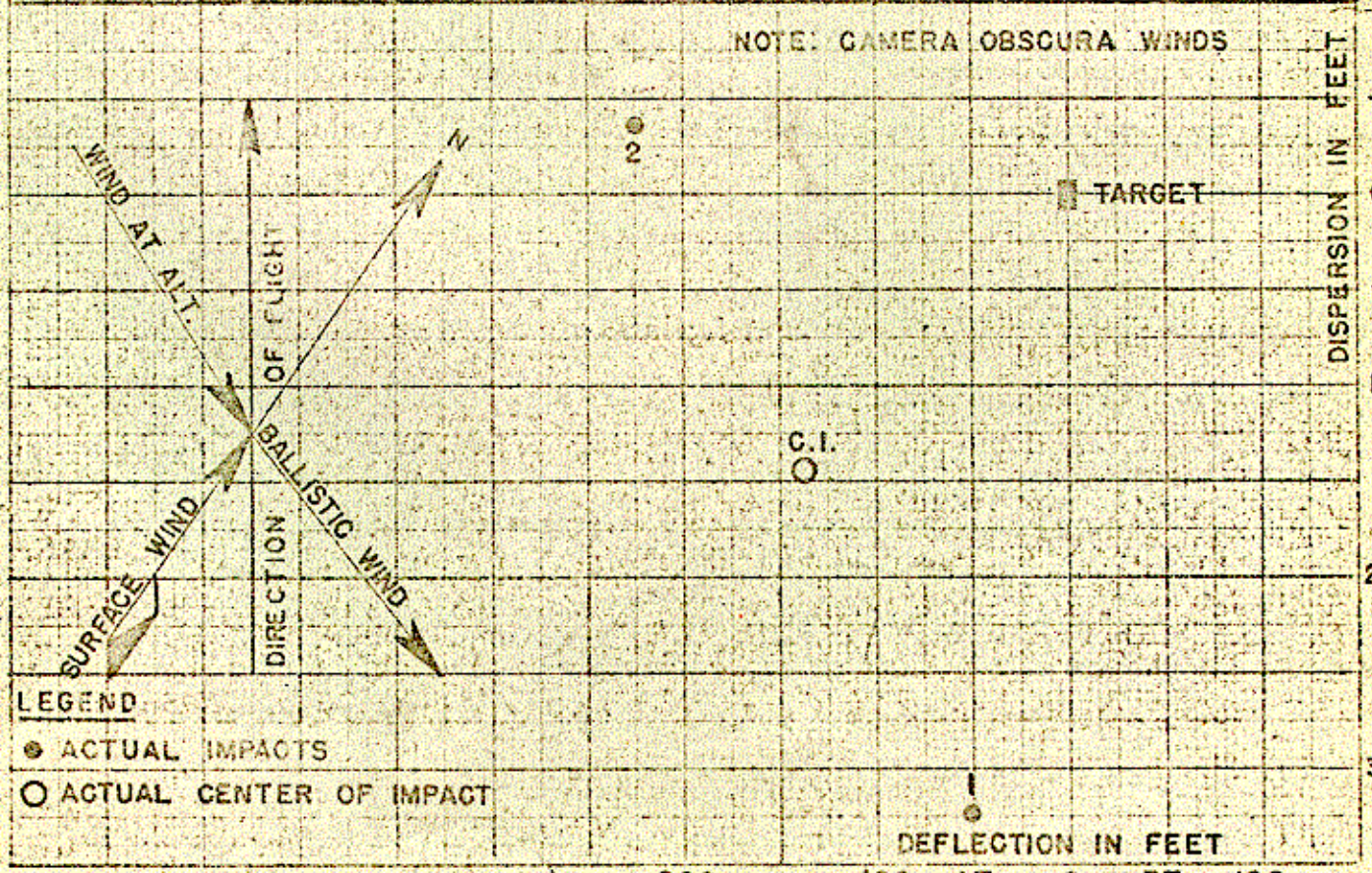
PILOT: LIEUT. G. HATCHER — BOMBARDIER: LIEUT. M.F. SUMMERFELT

SKY: NO CLOUDS · AIR: SMOOTH — TRAIL AND D.S. BASED ON BT-1100-A-2

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS FT.	ALTITUDE GR'ND OBS FT.	AIR SPEED CAL IND M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	DEVIATIONS FROM TARGET RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	10:09	10540	10500	143	168.8	172.1	159.1	+117.4	5826		324		51
2	10:19	10560	10598	143	169.1	168.2	155.5	+366.5	5686	36			225
3													
4													
5													
6													
CENTER OF IMPACT											144		138
MEAN DEVIATION										180		87	

		R.O.S.	R.O.S.	CAMERA
TIME		9:45		10:21
WIND VELOCITY M.P.H.	SURFACE			5.0
	AT ALTITUDE			14.3
	BALLISTIC RANGE WIND			-11.2
	BALLISTIC CROSS WIND			8.6
DENSITY	AT SURFACE	0.966		0.997
	BALLISTIC (SURFACE)	0.985		1.005
	BALLISTIC (AIR OBS.)	1.000		

NOTE: CAMERA OBSCURA WINDS



RESULTS OF RANGE BOMBING NO. 115

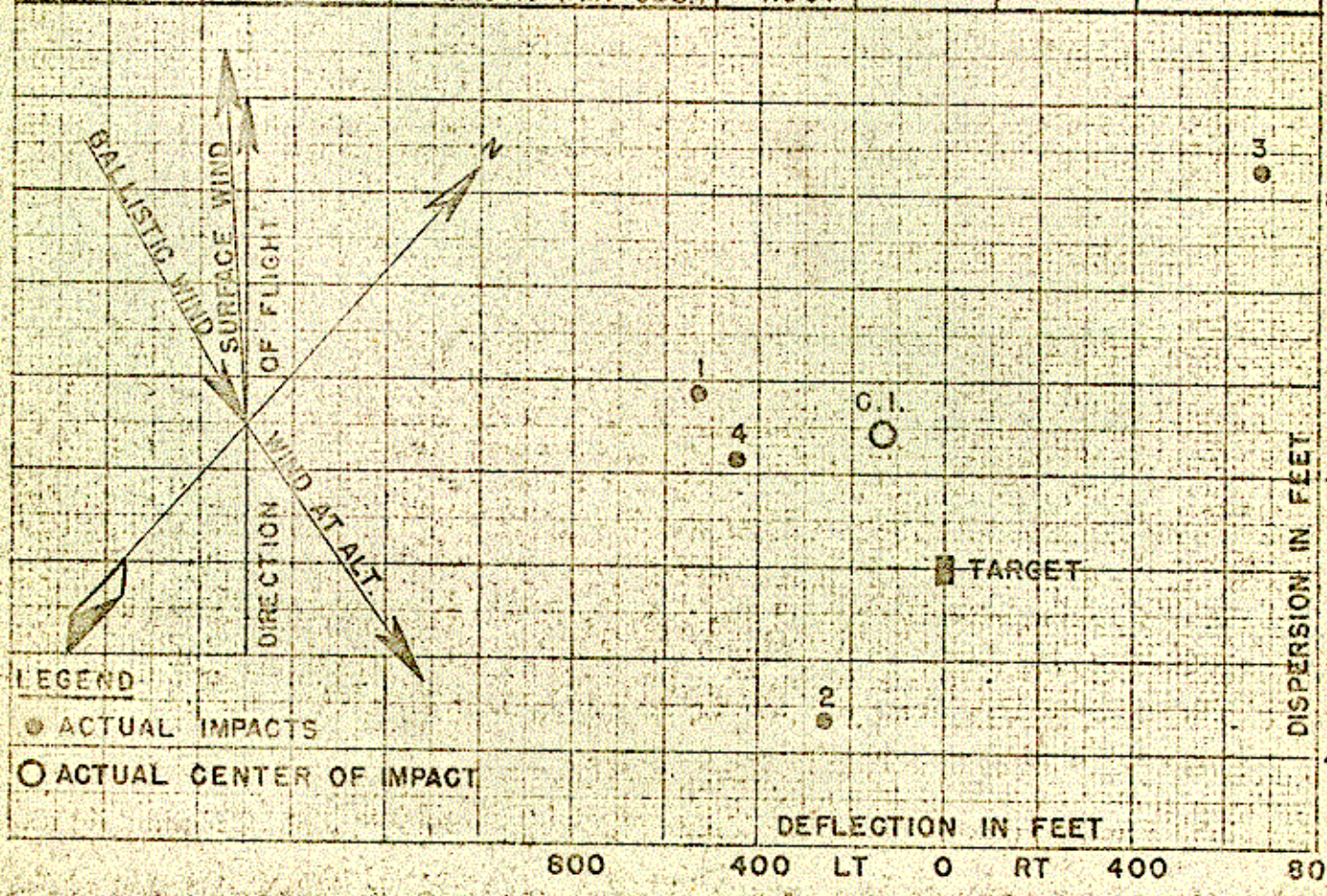
OCT. 22, 1940 — 1100 LB DEMOLITION BOMB M33 — AIRPLANE B-17B

PILOT: CAPT. M.J. LEE — BOMBARDIER: LIEUT. M.F. SUMMERFELT

SKY: NO CLOUDS — AIR: — TRAIL AND D.S. BASED ON BT-1100-A-2

BOMB NO.	TIME OF REL.	ALTITUDE AIR OBS. FT.	ALTITUDE GR'ND OBS. FT.	AIR SPEED CAL IND M/HR	AIR SPEED TRUE AIR OBS. M/HR	AIR SPEED TRUE GR'ND OBS. M/HR	GR'ND SPEED GR'ND OBS. M/HR	CLIMB OR GLIDE GR'ND OBS. FT/MIN	HOR. RANGE FT.	DEVIATIONS FROM TARGET: RANGE OVER FT.	RANGE SHORT FT.	DEFLECTION RIGHT FT.	DEFLECTION LEFT FT.
1	2:37	25430	25463	145	216.8	220.6	187.3	+ 28.1	10506	372			528
2	2:47	25410	25442	145	216.7	223.7	192.4	- 6.2	10311		327		258
3	2:56	25410	25477	149	222.8	230.1	197.1	+ 25.9	11464	858		678	
4	3:07	25420	25553	149	223.1	218.5	196.7	-229.6	11153	231			444
5													
6													
CENTER OF IMPACT										284			138
MEAN DEVIATION										332		408	

		R.O.S.	R.O.S.	CAMERA
TIME		1:59	3:00	3:07
WIND VELOCITY M.P.H.	SURFACE	8.0	6.0	7.0
	AT ALTITUDE	40.1	38.8	37.6
	BALLISTIC RANGE WIND	-26.3		-21.4
	BALLISTIC CROSS WIND	14.8		14.6
DENSITY	AT SURFACE	1.057	1.059	1.045
	BALLISTIC (SURFACE)	1.031	1.032	1.027
	BALLISTIC (AIR OBS.)	1.007		



RESULTS OF RANGE BOMBING NO. 117

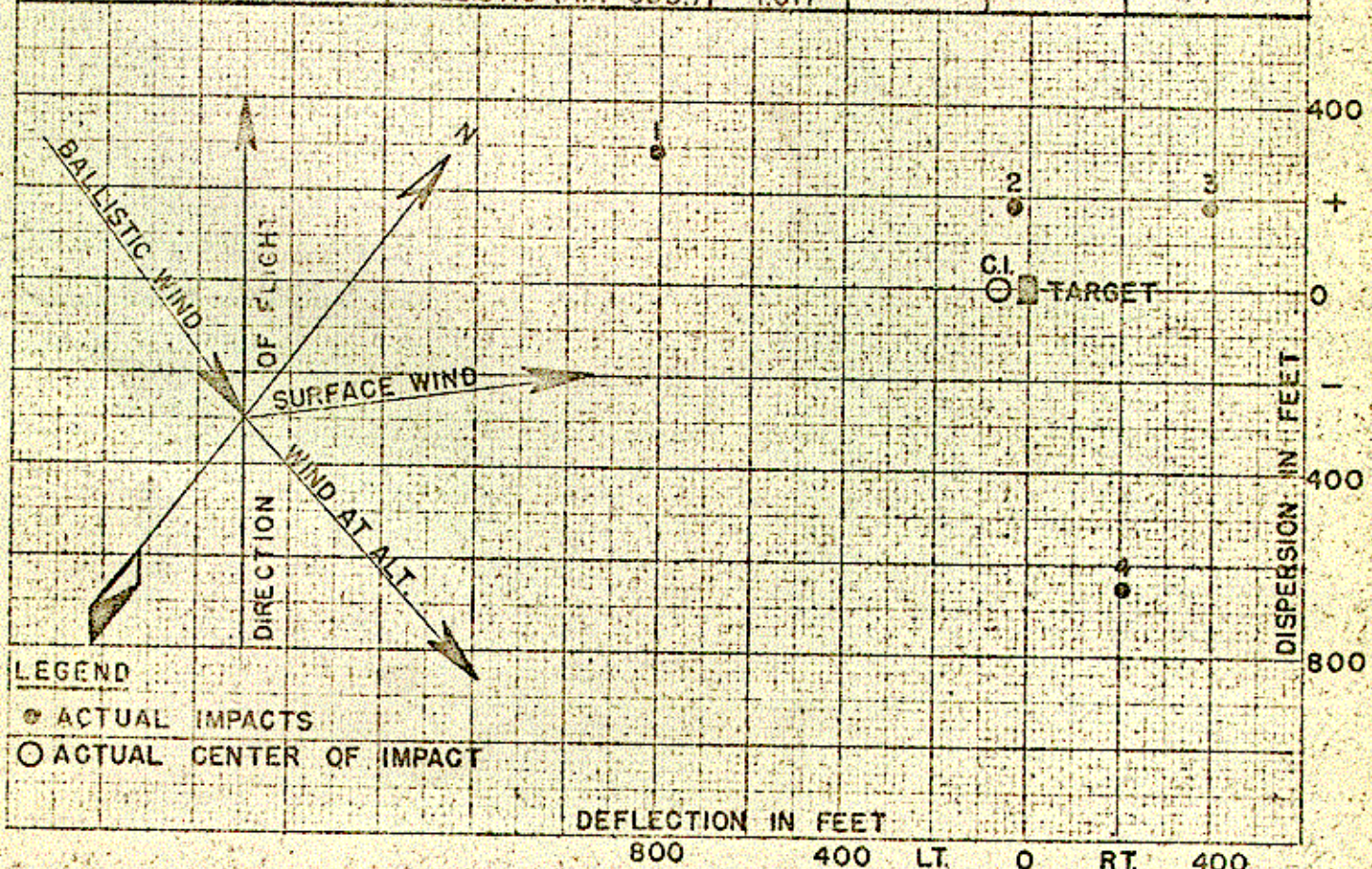
NOV. 4, 1940 — 1100 LB. DEMOLITION BOMB M33 — AIRPLANE B-17B

PILOT: LT. COOPER — BOMBARDIER: SGT. S.C. SMINK

SKY: — AIR: UNSTABLE — TRAIL AND D.S. BASED ON BT-1100-A-2

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
					TRUE					RANGE		DEFLECTION	
		AIR OBS FT.	GR'ND OBS FT.	CAL IND M/HR	AIR OBS. M/HR	GR'ND OBS. M/HR	GR'ND OBS. M/HR	GR'ND OBS. FT/MIN	FT.	OVER FT.	SHORT FT.	RIGHT FT.	LEFT FT.
1	3:00	26240	25768	144	216.3	225.5	173.9	- 27.5	10004	288			807
2	3:25	26250	25773	144	216.3	224.0	173.7	+486.8	9706	180			33
3	3:38	26240	25672	143	214.5	225.8	177.3	+ 31.3	10029	180		390	
4	3:53	26240	25649	143	214.4	225.3	177.1	- 334.6	9173		651	204	
5													
6													
								CENTER OF IMPACT			1		62
								MEAN DEVIATION		325		373	

		R.O.S.	R.O.S.	CAMERA
TIME		2:50	4:05	4:00
WIND VELOCITY M.P.H.	SURFACE	13.0	11.0	12.0
	AT ALTITUDE		59.7	49.0
	BALLISTIC RANGE WIND	-32.8		-25.3
	BALLISTIC CROSS WIND	24.0		20.1
DENSITY	AT SURFACE	1.010		1.013
	BALLISTIC (SURFACE)	1.014		1.015
	BALLISTIC (AIR OBS.)	1.017		



RESULTS OF RANGE BOMBING NO. 120-121

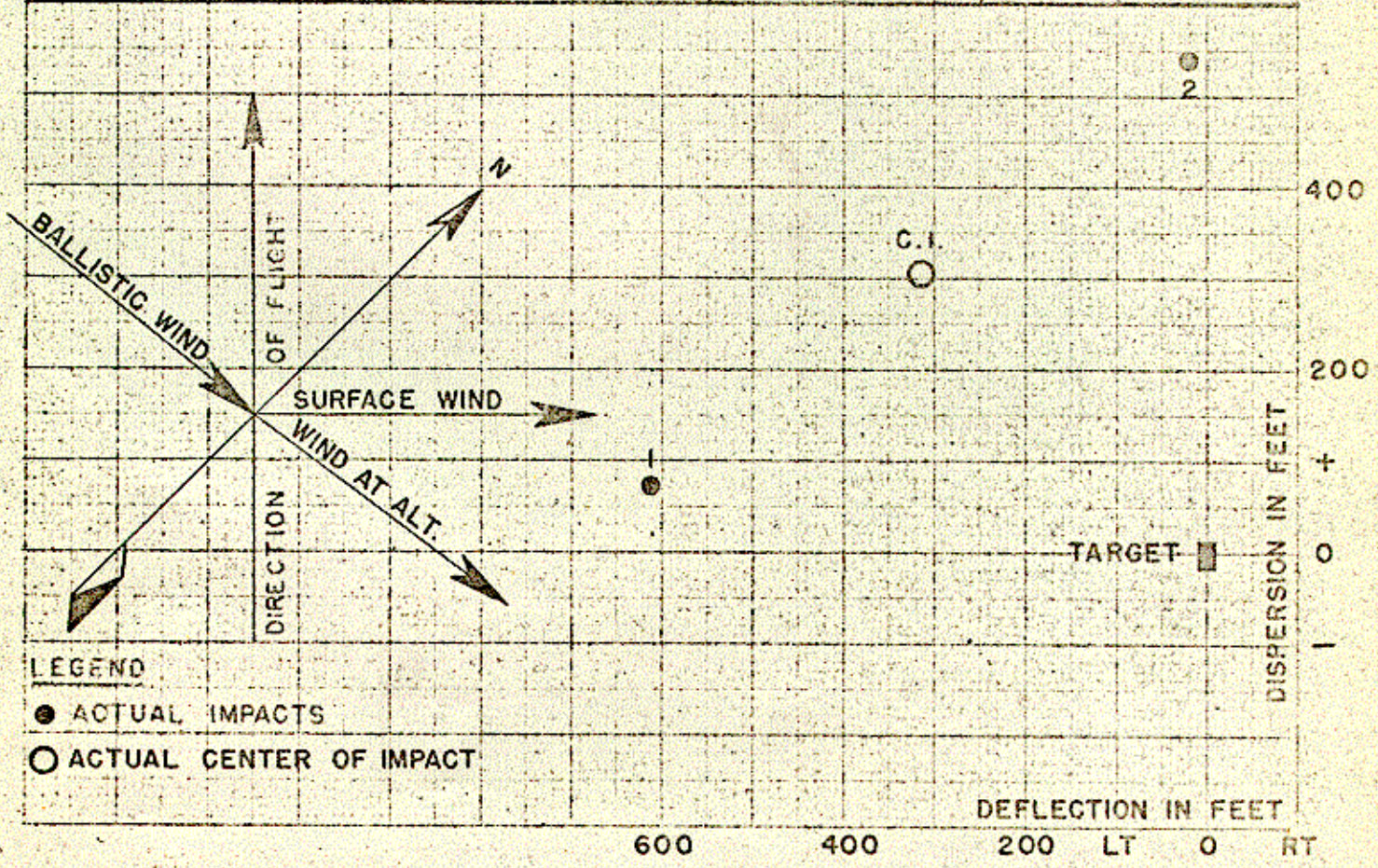
NOV. 20, 1940 — 1100 LB DEMOLITION BOMB M33 — AIRPLANE B-17B

PILOT: LIEUT. H. ESTES — BOMBARDIER: W.O. S.C. SMINK

SKY: SCTTRD CLOUDS AIR: VERY HAZY TRAIL AND D.S. BASED ON BT-1100-A-2

BOMB NO.	TIME OF REL.	ALTITUDE		AIR SPEED			GR'ND SPEED	CLIMB OR GLIDE	HOR. RANGE	DEVIATIONS FROM TARGET			
		AIR OBS	GR'ND OBS	CAL IND	TRUE					RANGE		DEFLECTION	
					AIR OBS.	GR'ND OBS.	GR'ND OBS.	GR'ND OBS.		OVER	SHORT	RIGHT	LEFT
		FT.	FT.	M/HR	M/HR	M/HR	M/HR	FT/MIN	FT.	FT.	FT.	FT.	FT.
1	10:15	25430	25526	152	227.5	219.2	162.3	-100.7	8626	72			612
2	10:28	23250	23496	149	215.9	219.5	170.6	-34.9	9173	540			21
3													
4													
5													
6													
CENTER OF IMPACT										306			317
MEAN DEVIATION										234		296	

			R.O.S.	R.O.S.	CAMERA
TIME			9:36	10:45	11:28
WIND VELOCITY M.P.H.		SURFACE	12.0	13.0	6.0
		AT ALTITUDE	79.3	80.0	70.6
		BALLISTIC RANGE WIND	-36.0		-33.2
		BALLISTIC CROSS WIND	+44.4		+39.5
DENSITY		AT SURFACE	1.054	1.046	1.043
		BALLISTIC (SURFACE)	1.031	1.028	1.026
		BALLISTIC (AIR OBS.)	1.017		



Appendix C

Individual Standard Elements and Ballistic Coefficients from Reduction of Field Data

Appendix C

Program Group Serial Number	Date of Release Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
KS-126--2	6/6/38--2	10000	160	5735	25.41	228	4.69	3.55	3.97
3	3			5755	25.49	227	5.63	3.13	4.13
1	6/14/38-1	10000	160	5704	25.12	191	3.69	9.70	5.00
4	2			5699	25.10	191	3.55	10.20	4.95
5	6/30/38-1	10000	160	5669	25.51	317	2.93	3.05	2.99
6	2			5762	25.29	173	6.09	4.75	5.41
8	8/19/38-3	15000	160	6854	31.68	580	2.46	2.48	2.47
7	4			7004	31.33	348	4.83	3.60	4.13
10	5			7033	31.53	366	5.88	2.86	3.97
9	6			7019	31.33	333	5.27	3.60	4.31
11	8/22/38-2	5000	160	4184	18.04	48	-6.23	1.94	4.46
12	8/23/38-2	15000	160	6884	32.06	639	2.74	1.84	2.21
13	8/29/38-1	5000	160	4055	17.91	148	3.34	2.85	3.15
14	5/24/39-1	2000	160	2616			82.41		
15	2			2606	11.25	33	9.79	2.97	5.29
16	3			2616	11.20	13	98.90	5.44	13.64
17	4			2628	11.23	8	-12.49	3.46	22.28
18	5			2611	11.23	26	16.49	3.40	6.89
1	7/6/40--1	10000	160	5661	24.99	204	2.81	33.87	4.67
2	2			5744			5.00		
4	7/10/40-1	10000	160	5722	25.25	203	4.17	5.63	4.70
3	2			5664	25.17	243	2.87	7.48	3.93
8	10/22/40-1	25000	200	11240	41.10	816	5.01	3.74	4.27
7	2			10835	41.32	1285	2.15	3.25	2.60
6	3			11584[1]	41.12			3.68	

[1] Not included in group mean for the reason given on page 8 of text.

Appendix C (Cont'd)

Program Group Serial Number	Date of Release Run No.	Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	X Standard Range ft.	T Standard Time of Flight sec.	λ Standard Trail ft.	C_X	C_T	C_λ
KS-126--5	10/22/40-4	25000	200	11366	41.35	764	8.25	3.18	4.57
11	11/4/40--1	25000	200	11412			10.79		
12	2			11089	39.76	572	3.38	21197	6.37
					WE 40.24	716		8.30	4.97
9	3			11283			5.81		
10	4			10650			1.69		
13	11/20/40-1	25000	200	10846	41.05	1194	2.19	3.87	2.84
14	2			11209	40.50	670	4.57	6.17	5.28

Appendix D

Mean Standard Elements of Altitude Groups and Relations Between the Ballistic Coefficients and the Altitude of Release

Appendix D
Table 1
Range

Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	V Calibrated Indicated Air Speed Corresponding to Standard True Air Speed mi./hr.	N Number of Bombs	P Weight of Groups	X Mean Standard Range ft.	r_X Probable Error of Mean Standard Range ft.	C_X Ballistic Coefficient Corresponding to Mean Standard Range	r_{C_X} Probable Error of Ballistic Coefficient Corresponding to Mean Standard Range	C_{X_y} Value of Ballistic Coefficient from C:Y Relation	$X-X_f$ Mean Standard Range Minus Range Corresponding to C_{X_y} ft.
35000									3.23	
30000									3.31	
25000	200	134.8	9	1.16	11103	60.0	3.49	0.472	3.41	11
20000									3.55	
15000	160	126.3	5	0.00	6959	25.1	3.81	0.476	3.79	- 4
10000	160	136.6	10	1.72	5712	8.1	3.85	0.225	4.27	-14
5000	160	147.9	2	0.26	4120	43.6	15.04	35.06	5.98	28
2000	160	155.0	5	0.86	2616	42.5	57.80	75.46	28.88	2

Appendix D
Table 2
Time of Flight

Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	V Calibrated Indicated Air Speed Corresponding to Standard True Air Speed mi./hr.	N Number of Bombs	P Weight of Groups	T Mean Standard Time of Flight sec.	r_T Probable Error of Mean Standard Time of Flight sec.	C_T Ballistic Coefficient Corresponding to Mean Standard Time of Flight	r_{C_T} Probable Error of Ballistic Coefficient Corresponding to Mean Standard Time of Flight	C_{T_y} Value of Ballistic Coefficient from C:Y Relation	$T-T_f$ Mean Standard Time of Flight Minus Time of Flight Corresponding to C_{T_y} sec.
35000									4.84	
30000									4.81	
25000	200	134.8	7	1.16	40.80	0.137	4.66	0.520	4.78	0.03
20000									4.74	
15000	160	126.3	5	0.00	31.59	0.092	2.69	0.237	4.69	0.43
10000	160	136.6	9	1.72	25.26	0.041	5.46	0.698	4.60	-0.06
5000	160	147.9	2	0.26	17.97	0.043	2.31	0.295	4.40	0.16
2000	160	155.0	4	0.86	11.23	0.006	3.64	0.293	4.06	0.01

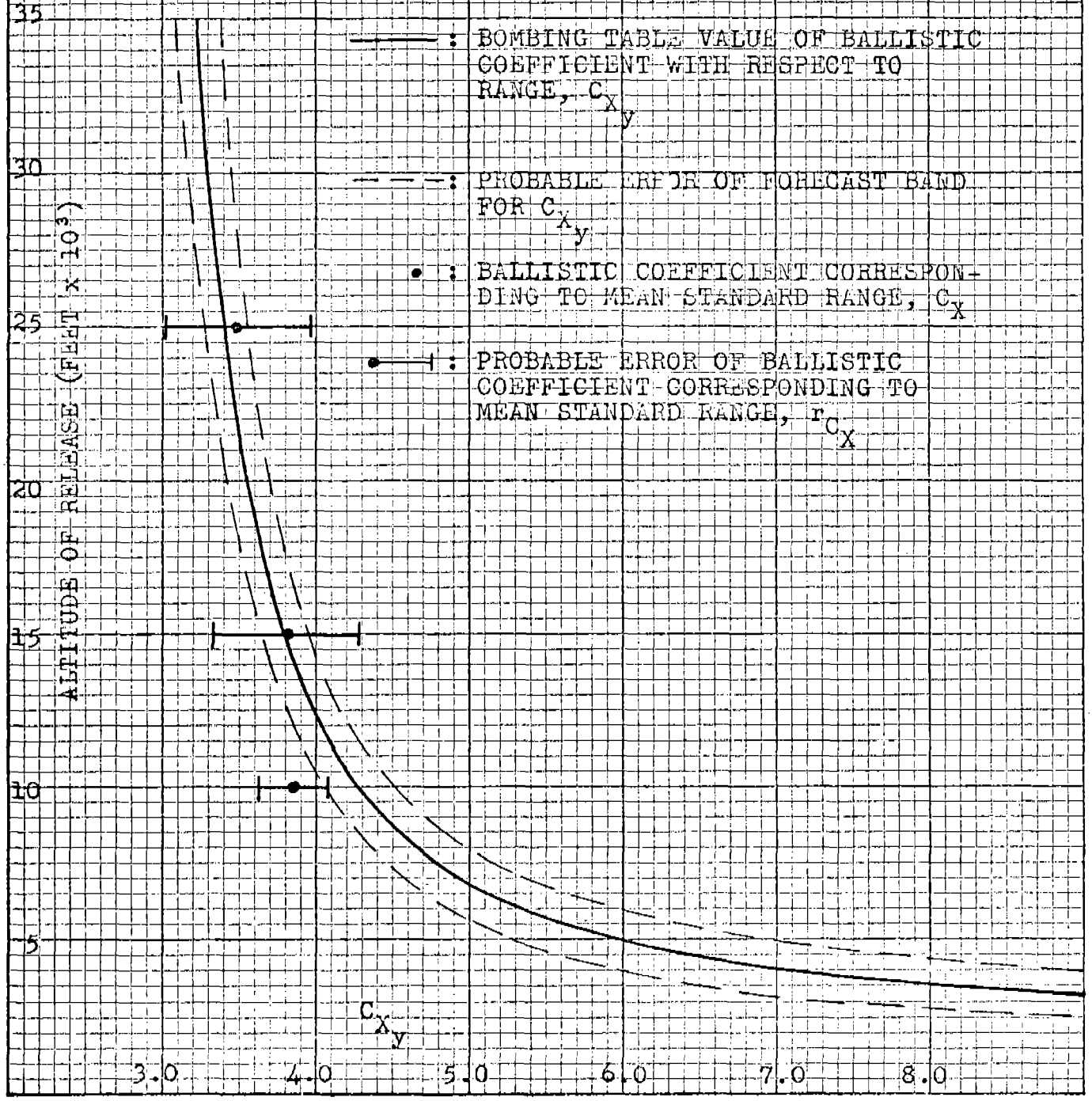
Appendix D
Table 3
Trail

Y Standard Altitude ft.	U Standard True Air Speed mi./hr.	V Calibrated Indicated Air Speed Corresponding to Standard True Air Speed mi./hr.	N Number of Bombs	P Weight of Groups	λ Mean Standard Trail ft.	r_λ Probable Error of Mean Standard Trail ft.	C_λ Ballistic Coefficient Corresponding to Mean Standard Trail	r_{C_λ} Probable Error of Ballistic Coefficient Corresponding to Mean Standard Trail	C_{λ_y} Value of Ballistic Coefficient from C:Y Relation	$\lambda-\lambda_f$ Mean Standard Trail Minus Trail Corresponding to C_{λ_y} ft.
35000									3.90	
30000									3.95	
25000	200	134.8	7	1.16	860	69.3	4.04	0.361	4.01	-6
20000									4.09	
15000	160	126.3	5	0.00	453	43.6	3.20	0.315	4.22	110
10000	160	136.6	9	1.72	220	9.6	4.34	0.190	4.46	6
5000	160	147.9	2	0.26	98	33.5	4.73	1.629	5.12	8
2000	160	155.0	4	0.86	20	3.9	8.80	1.72	7.25	-4

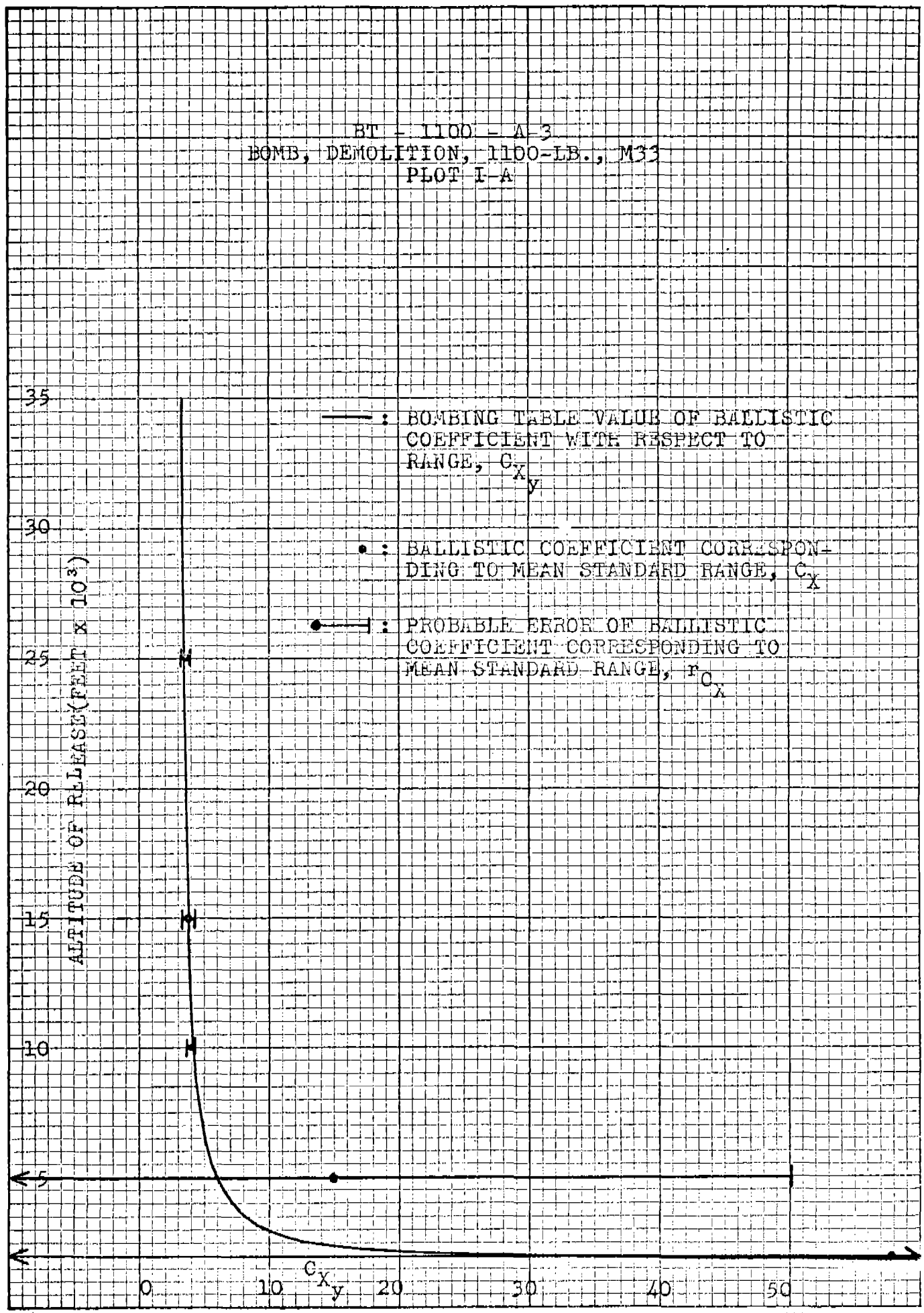
BT - 1100 - A-3

BOMB, DEMOLITION, 1100-LB., M33

PLOT I



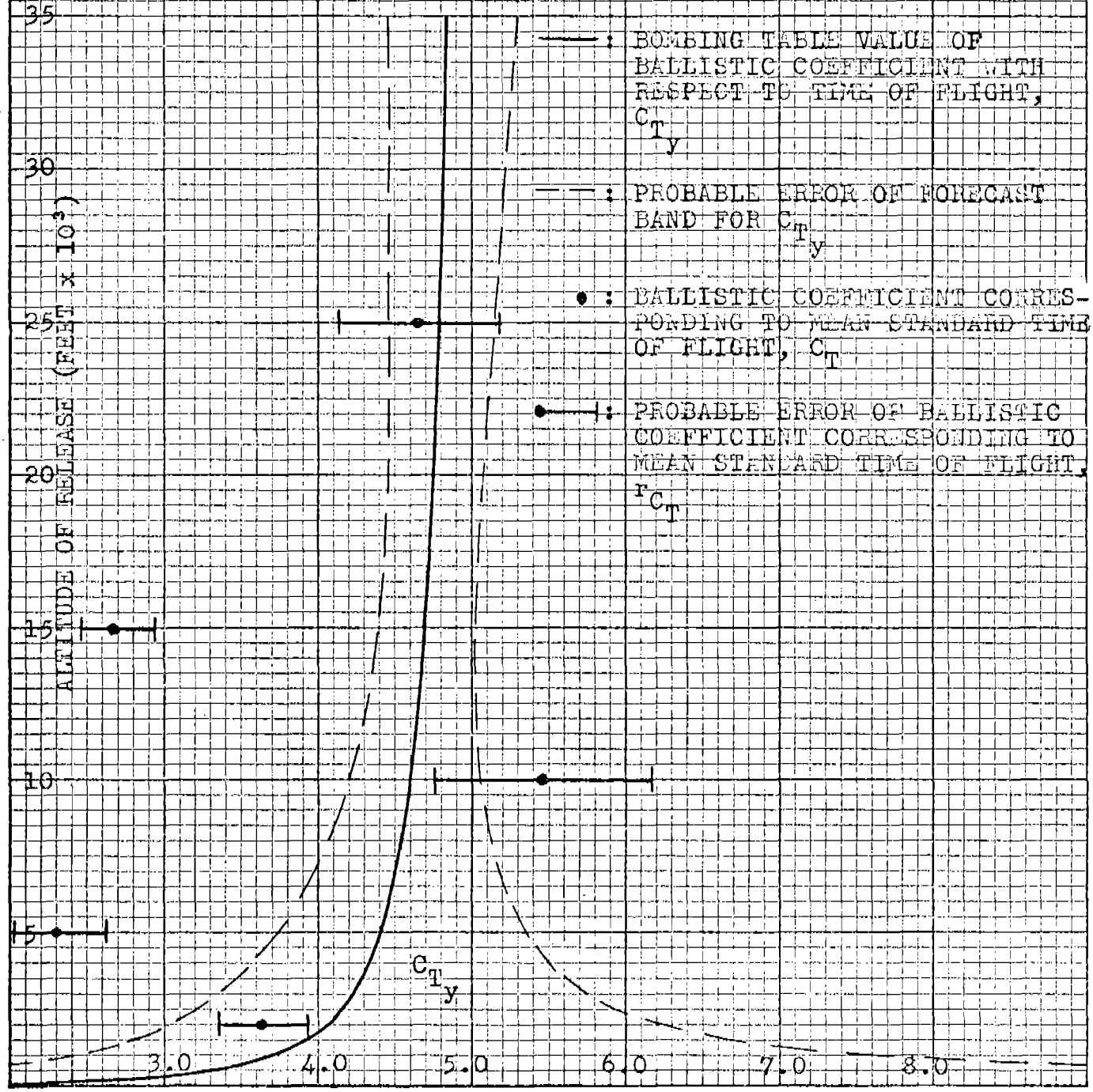
BT - 1100 - A-3
BOMB, DEMOLITION, 1100-LB., M33
PLOT I-A



BT - 1100 - A-3

BOMB, DEMOLITION, 1100-LB., M33

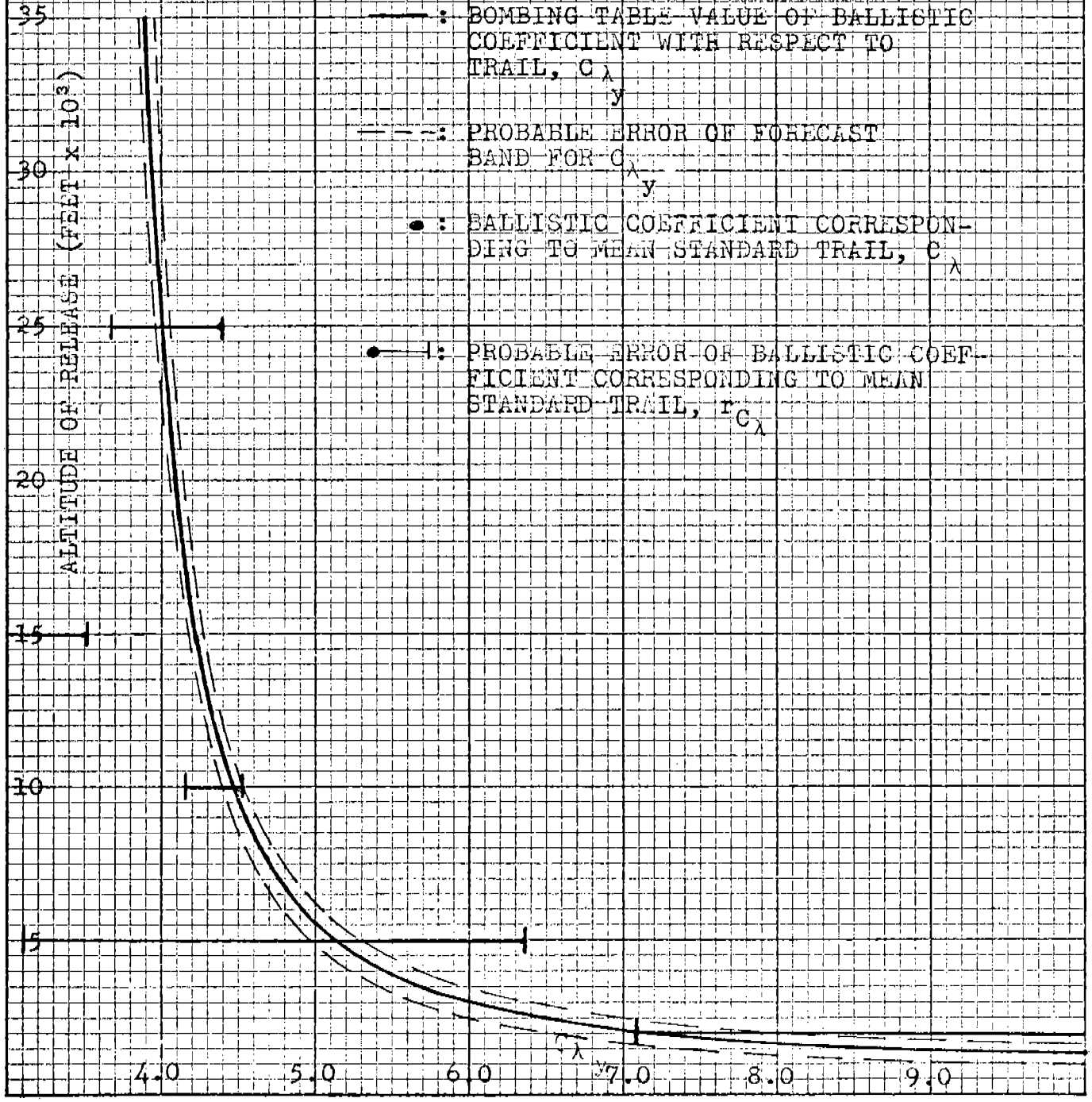
PLOT II

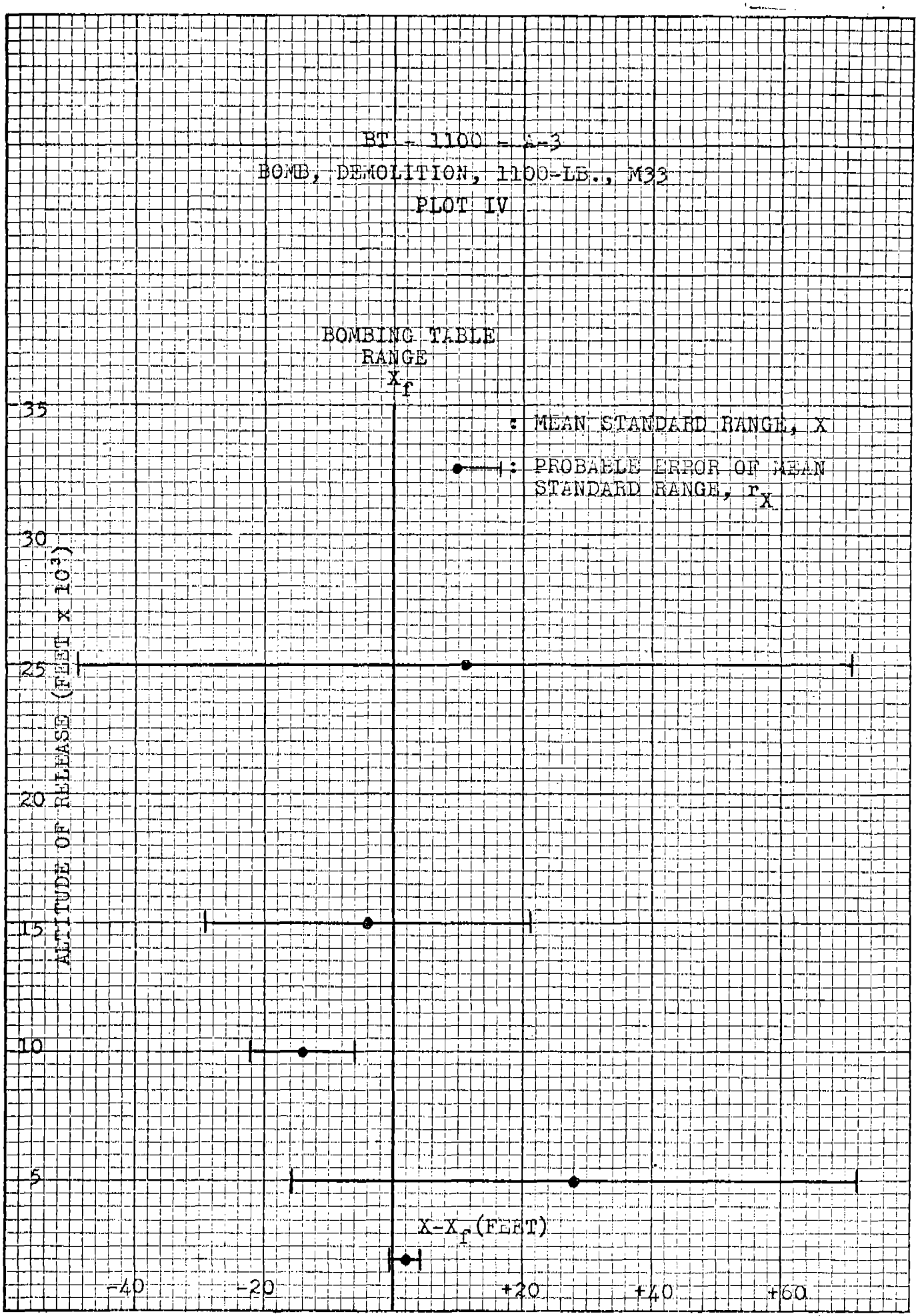


BT - 1100 - A-3

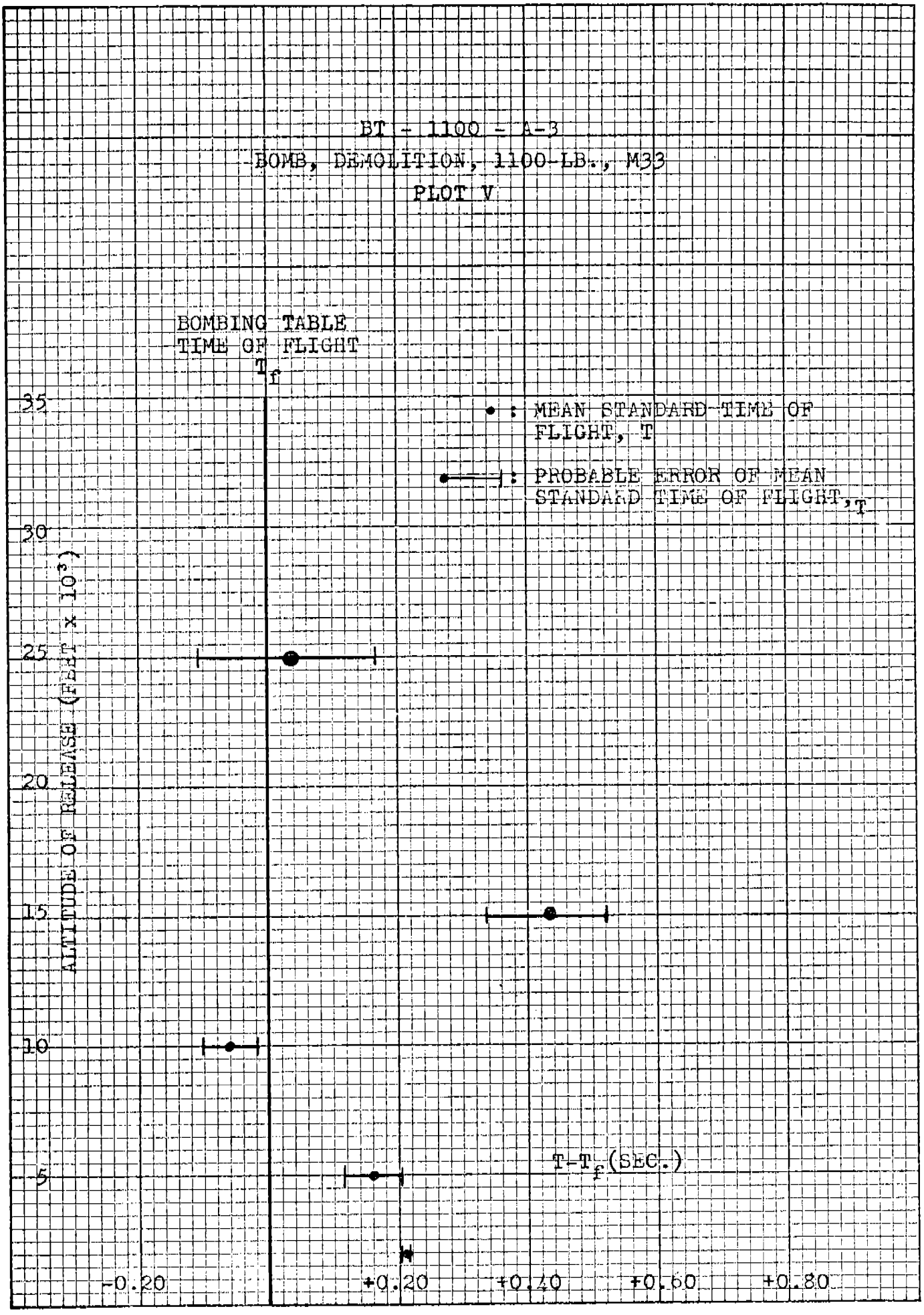
BOMB, DEMOLITION, 1100-LB., M33

PLOT III




BT - 1100 - A-3
BOMB, DEMOLITION, 1100-LB., M33
PLOT IV
BOMBING TABLE
RANGE
X_f
: MEAN STANDARD RANGE, X
: PROBABLE ERROR OF MEAN STANDARD RANGE, r_X
ALTITUDE OF RELEASE (FEET X 10^3)
35
30
25
20
15
10
5
$X-X_f$ (FEET)
-40
-20
+20
+40
+60

BT - 1100 - A-3

BOMB, DEMOLITION, 1100-LB., M33

PLOT V